MEET THE 10 NEAREST STARS p. 36

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DEEP-SKY OBJECTS IN ARA p. 26

IOPTRON'S NEW MOUNT REVIEWED p. 48

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CONTENTS

JUNE 2023
VOL. 51, NO. 6

ON THE COVER

The celebrated "Pillars of Creation" in the Eagle Nebula typify revolutionary imaging from the Webb Space Telescope. JWST: NASA/ESA/CSA/STSCI/J. DEPASQUALE, A. KOEKEMOER, A. PAGAN (STSCI); HUBBLE: NASA/ESA/THE HUBBLE HERITAGE TEAM (STSCI/AURA)

FEATURES

14 COVER STORY
How the Webb telescope is changing astronomy
With its penetrating infrared gaze, JWST is revealing planets, stars, and more in a whole new light.
RICHARD TALCOTT

22
First look at October's annular eclipse
This fall, viewers along a narrow path can see a perfect ring of light in the daytime sky.
MICHAEL E. BAKICH

26
Observe the deep sky in Ara
This small, often-overlooked constellation contains several observing treasures worth your while. **MICHAEL E. BAKICH**

28
Sky This Month
Buzzing through the Beehive.
MARTIN RATCLIFFE AND ALISTER LING

30
Star Dome and Paths of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

36
Explore the 10 nearest stars
Take a trip around the galactic block and get to know your stellar neighbors.
STEPHEN ORNES

44
Blasts from the past
Supernova remnants are colorful tendrils of gas left by exploding stars — and are a worthy challenge to observe.
F. MICHAEL WITKOSKI

48
Navigate the stars with a new type of mount
With a center-balanced design, iOptron's CEM70 is great for observers and astrophotographers.
TONY HALLAS AND FRANK DIBBELL

54
Ask Astro
Imaging the Sun.

COLUMNS

Strange Universe 13
BOB BERMAN

Secret Sky 50
STEPHEN JAMES O'MEARA

Binocular Universe 52
PHIL HARRINGTON

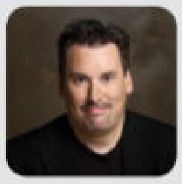
7
QUANTUM GRAVITY
Everything you need to know about the universe this month: old, giant galaxies challenge cosmology, a new type of ice is found, a dwarf planet puts a ring on it, and more.

IN EVERY ISSUE

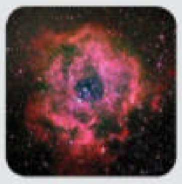
From the Editor 4
Astro Letters 6
New Products 53
Advertiser Index 53
Reader Gallery 56
Breakthrough 58

ONLINE FAVORITES

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.



Dave's Universe
The inside scoop from the editor.



Picture of the Day
Gorgeous photos from our readers.

News
The latest updates from the science and the hobby.

My Science Shop
Perfect gifts for your favorite science geeks.

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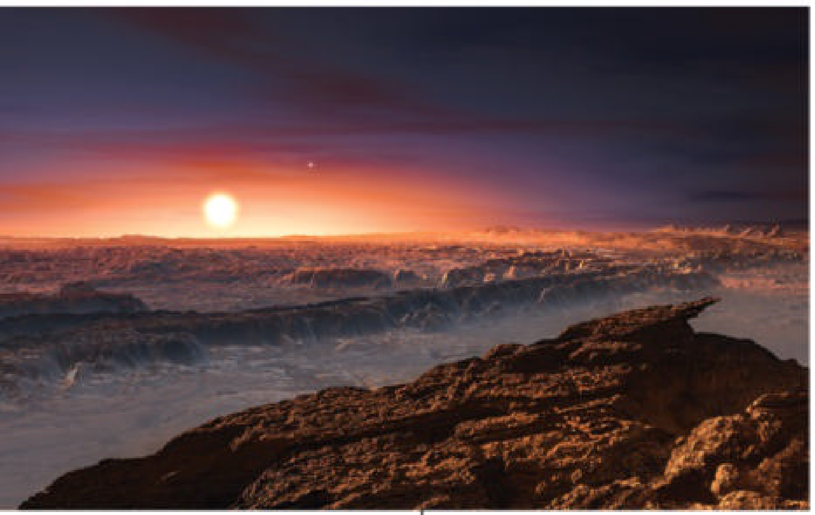
FROM THE EDITOR

A vast canvas



The nearest star to the Sun, Proxima Centauri, lies on the horizon in this artwork showing it from an orbiting planet. ESO/M. KORNMESSER

When we look up into a dark sky, we're accustomed to seeing the cosmos as an unimaginably faraway thing. Distances don't really register. The few things we can see move in short intervals — the Sun, Moon, and planets — are exceptions. Everything else may as well be painted onto a vast canvas in the heavens.

But of course, in reality we look out into an incredibly huge, three-dimensional space with countless objects at all manner of distances. In this issue, science writer Stephen Ornes introduces us to a special class, the 10 nearest stars. These closest celestial neighbors beyond our own solar system have lots to tell us about stars, about stellar evolution, and about the space around us in the Milky Way Galaxy.

You probably know that the closest star to us is Proxima Centauri, an M (red) dwarf a hair over 4.2 light-years away that orbits its main binary system of Alpha Centauri A and B. Although this triple system is very close on a galactic scale, such distances are vast. The fastest spacecraft we can realistically conceive of would take more than 70,000 years to travel to Proxima Cen.

Many more interesting stars lie in our cosmic neighborhood. Discovered by the great American astronomer Edward E. Barnard, Barnard's Star is the fastest-moving star in the sky, relative to the background. Another red dwarf, it speeds along at more than 10 arcseconds a year. Star of a *Star Trek* episode, our neighbor Wolf 359 is yet another red dwarf — you get the picture; they are the most common stars — just 7.9 light-years away. But our neighbors are not all red dwarfs. There is also the brightest star in the sky, main-sequence Sirius, which lies a mere 8.6 light-years away and hides a difficult-to-spot white dwarf companion.

Not only can we read about these close stars in our neighborhood, we can also observe them. The story includes finder charts for those who want to venture out with a telescope and peer closely at some of the closest stars to our Sun.

Yours truly,

David J. Eicher
Editor

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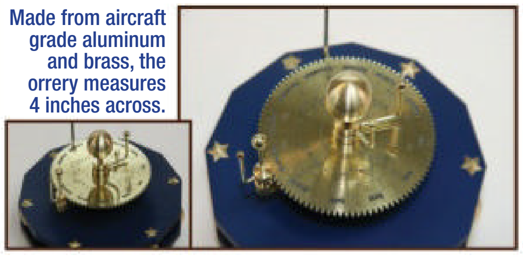

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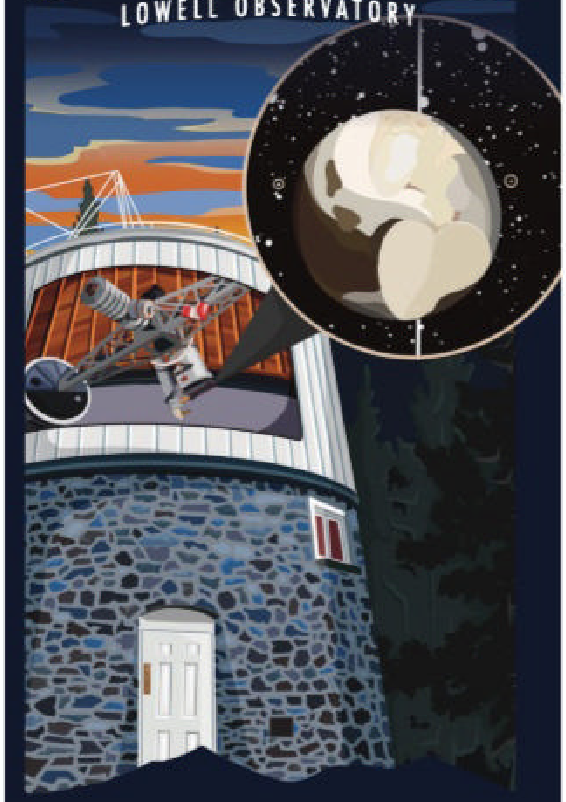

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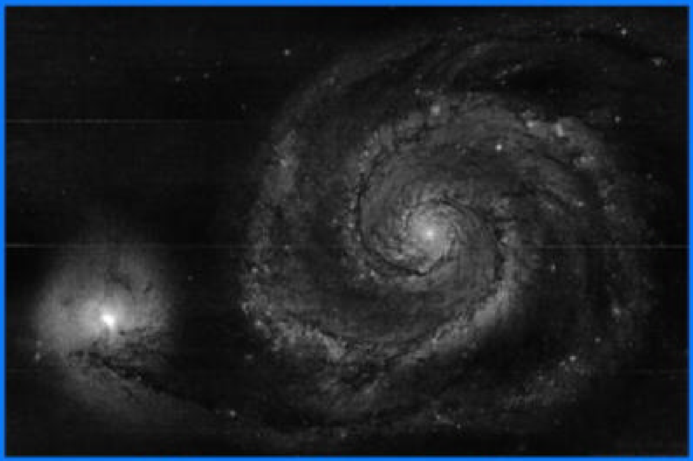

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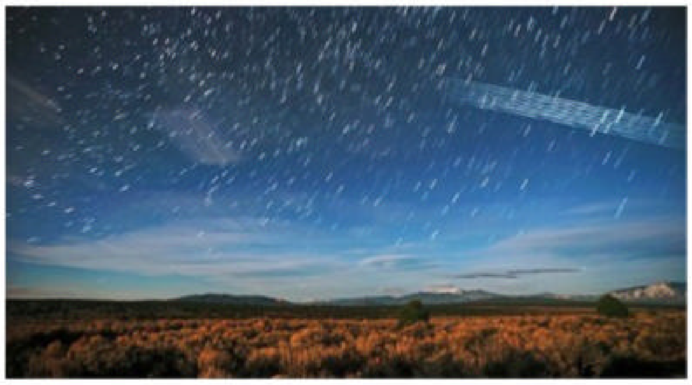


Starlink satellites (right) appear over Carson National Forest in New Mexico. The satellites provide internet in remote areas around the world, but are changing the look of the night sky. MIKE LEWINSKY/FLICKR (CC BY 2.0)

Dim the lights

I read "The satellite-streaked sky" in your March 2023 issue and shook my head in dismay. I'm a pilot and I have obtained wonderful views of the Milky Way and constellations. Unfortunately, I have also seen bright trains of satellites passing overhead.

I realize that they are brightest when deployed and will presumably fade once established in orbit, but with many thousands of satellites passing overhead, I fail to see how the effect will be anything less than cataclysmic to the field of astronomy. The only way that this will be even remotely tolerable would be for these satellites to be no brighter than an apparent magnitude of 7; at least the impact to the visual presentation of our sky to the naked eye might be acceptable. I think that article's authors may be correct in their assessment that the night sky may soon change, and certainly not for the better. **—Jeff Gebhart,** La Grange, IL

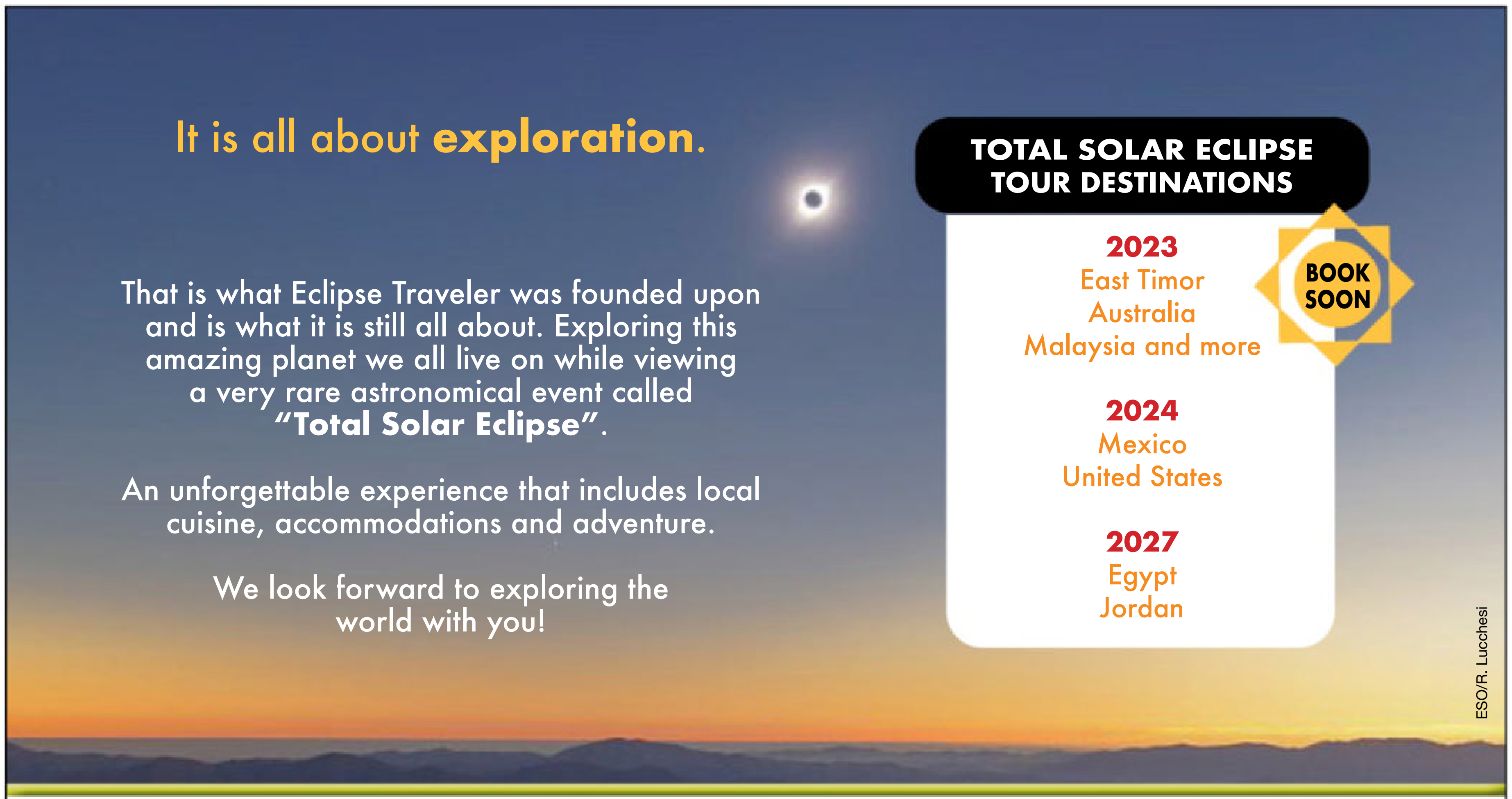
We welcome your comments at Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; or email to **letters@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Discovering details

Nowhere in the article on the U.S. Naval Observatory's 26-inch refractor (February 2023) is anything about its physical characteristics beyond the lens diameter. An email inquiry to the USNO for details on focal ratio and length was met with this information from Geoff Chester, public affairs officer: "As with most Clark refractors, the focal ratio is f/15, so the focal length is 390 inches (9900 mm). The subsequent large refractors that they built for Lick Observatory (36-inch) and Yerkes Observatory (40-inch) were figured to f/19 to keep the weight of the lenses from affecting the flexure of the tubes. The Clarks figured their lenses by a 'standard' formula that could be easily scaled to meet their production demands. They made a few lenses that were 'faster' (f/13 was about as low as they could go). All of the lenses' surfaces were spherical, and the f/15 and longer focal ratios limited spherical aberration." **—Rus Stolling,** Fresno, CA

Erratum

The "Anatomy of a comet" graphic in January's "Catching comets on camera" incorrectly labeled the comet's direction of travel; the arrow should be pointed the other way. Find the updated version at: https://astronomy.com/magazine/news/2023/01/how-to-catch-comets-on-camera.



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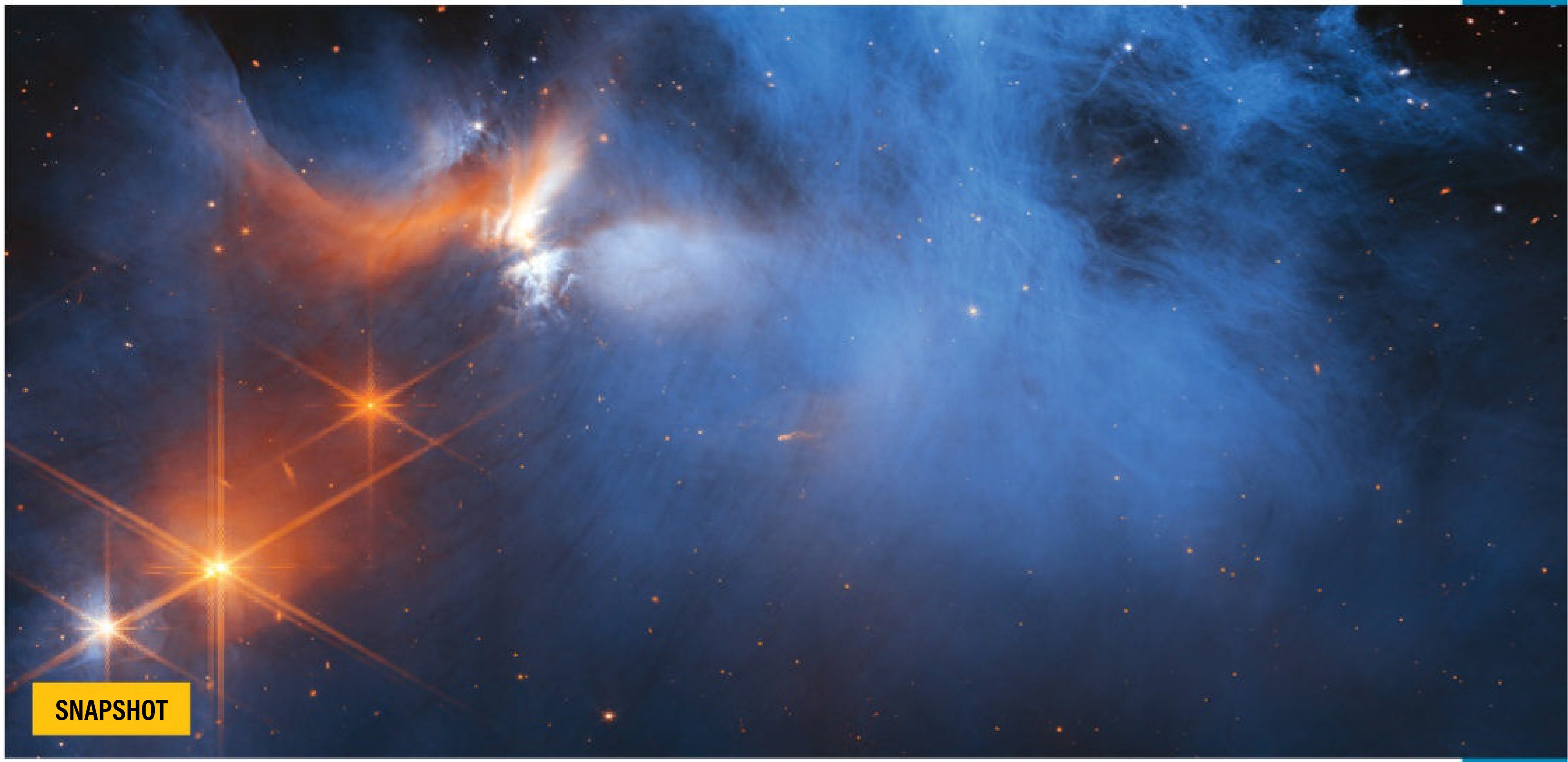
EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH



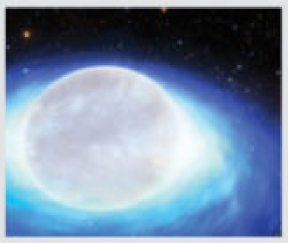
SNAPSHOT

THE CHAMELEON'S COLD HEART

JWST helps astronomers map the complex chemicals that could form life.

The molecular cloud Chameleon I features in this gorgeous image from the James Webb Space Telescope (JWST). It is one of the nearest star-forming regions to Earth, located just 630 light-years away. At upper left is a young protostar called Ced 110 IRS 4, whose light illuminates the dense, bluish cloud at the infrared wavelengths JWST observes. Just visible through the cloud at center are several small, pointlike background stars. By measuring the wavelengths of starlight absorbed by the cloud, researchers were able to identify ices present inside. JWST's observations revealed water, carbonyl sulfide, ammonia, methane, and methanol. There were also hints of even more complex molecules, such as ethanol. Such molecules are essential to life on Earth, and these data suggest they are widespread throughout the galaxy. —ALISON KLESMAN

» HOT BYTES



STAY TUNED

CPD–29 2176 is a binary with a neutron star whose formative supernova did not destroy its companion (which is also destined to be a neutron star). It's the first known system in the Milky Way that could trigger a kilonova — an explosive collision of neutron stars.

TOWERING FIGURE

The International Astronomical Union has given a 20,000-foot-tall (6,100 m) mountain near the Moon's south pole a name: Mons Mouton. It honors Melba Roy Mouton, a pioneering NASA mathematician and programmer.

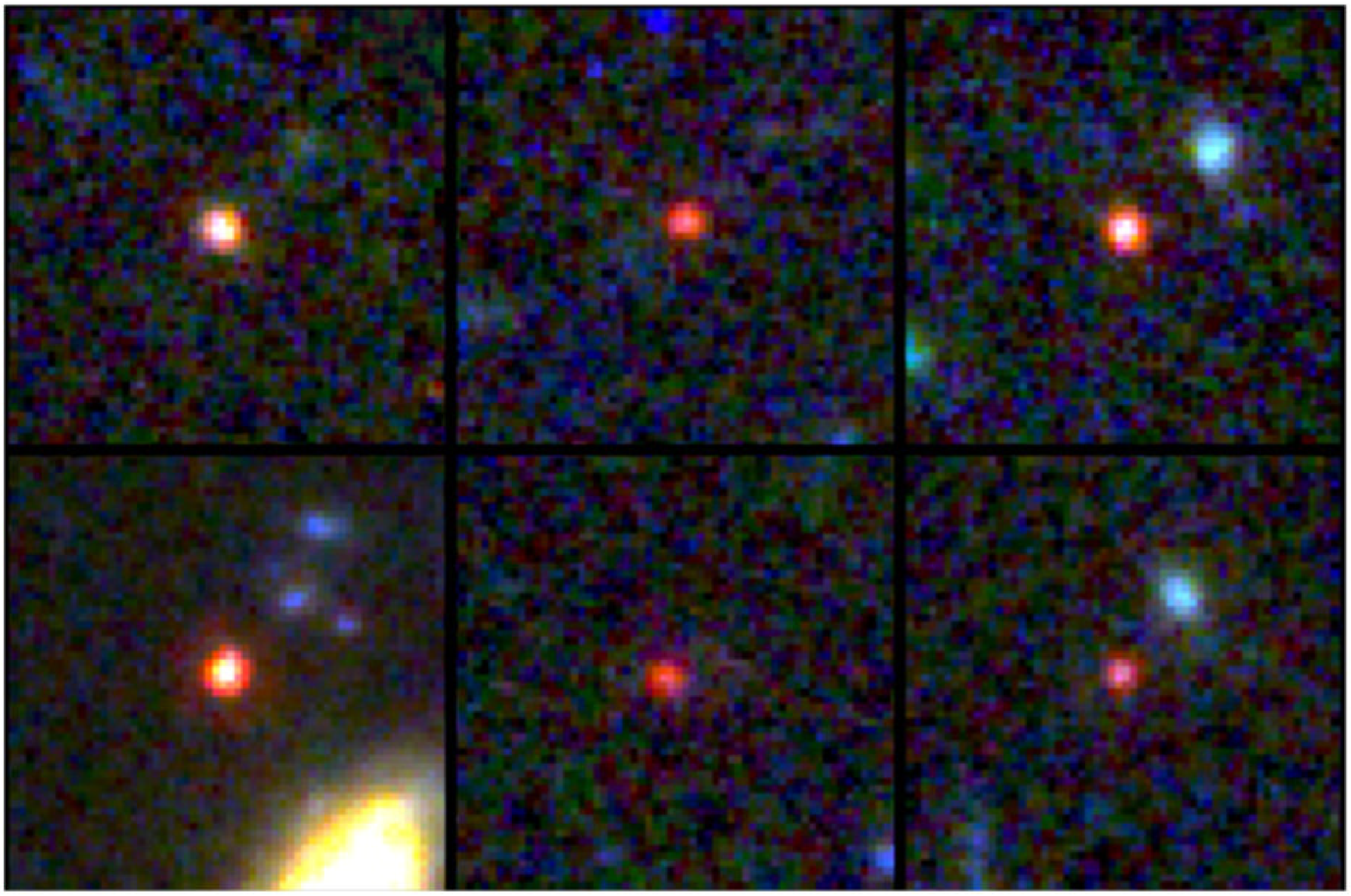
NUCLEAR EXPRESS

NASA will team with the Defense Advanced Research Projects Agency (DARPA) to design and fly a nuclear thermal rocket, which uses a fission nuclear reactor to heat an expanding propellant. Such engines could power crewed journeys to Mars.

IMAGE: NASA, ESA, CSA; SCIENCE: FENGWU SUN (STEWARD OBSERVATORY), ZAK SMITH (THE OPEN UNIVERSITY), ICEAGE ERS TEAM; IMAGE PROCESSING: M. ZAMANI (ESA/WEBB); BOTTOM FROM LEFT: CTIO/NOIRLAB/NSF/AURA/J. DA SILVA/SPACEENGINE/M. ZAMANI; NASA; DARPA

GIANT GALAXIES EMERGED EARLY IN THE DAWN OF THE UNIVERSE

These objects challenge cosmological models of how the universe evolved.



GROWTH SPURTS. The six galaxies spotted by JWST appear as the small red points in this image. Scientists didn't think galaxies this large could exist at such an early stage of the universe. NASA/ESA/CSA/I. LABBE (SWINBURNE UNIVERSITY OF TECHNOLOGY); IMAGE PROCESSING: G. BRAMMER (UNIVERSITY OF COPENHAGEN)

Astronomers using the James Webb Space Telescope (JWST) have found six massive galaxies with roughly as many stars as our own Milky Way, but in the cosmic dawn less than a billion years after the Big Bang.

These galaxies are not supposed to exist at such early times. Galaxies like our own take billions of years to amass their hundreds of billions of stars. To put it in perspective, a galaxy that is madly churning out stars produces only 100 Suns' worth of stars per year. And our own staid Milky Way makes only a handful of stars per year that together weigh about as much as our Sun. So, the galaxies spotted by JWST would have had to be massively productive since the dawn of the universe — and the first stars didn't even turn on until 100 million years after the Big Bang, shrinking the timeline even further.

What's more, standard cosmology states that at such early times, there simply wasn't enough baryonic matter — the normal stuff stars (and people and rocks) are made of — in a small enough area to make so many stars. Each of the galaxies discovered has tens of billions of stars, with some sporting perhaps as many as 100 billion stars. Most astronomers think it took the universe a few billion years to clump up enough to allow for massive galaxies. Until now, that's what observations have shown too: small galaxies with fewer stars in the early universe.

In other words, these newfound galaxies imply either that scientists are wrong about standard cosmology — always an exciting idea — or wrong about how galaxies form and evolve, which is equally intriguing.

Shared online as a preprint last July, the work was peer-reviewed and published by the journal *Nature* Feb. 22.

LOOKING FAR AFIELD

The data come from one of JWST's first projects — to observe a seemingly empty chunk of space near the Big

Dipper. By looking into the darkness, away from more obvious targets, telescopes can peer into the distant universe, revealing galaxies, quasars, and more from the first billion years of the universe. Dubbed the Cosmic Evolution Early Release Science (CEERS) Survey, the project was meant to gather a large batch of galaxy data from the distant universe. The Hubble Space Telescope looked at this same patch of sky in the 1990s and found plenty of small, early galaxies with few stars, as expected.

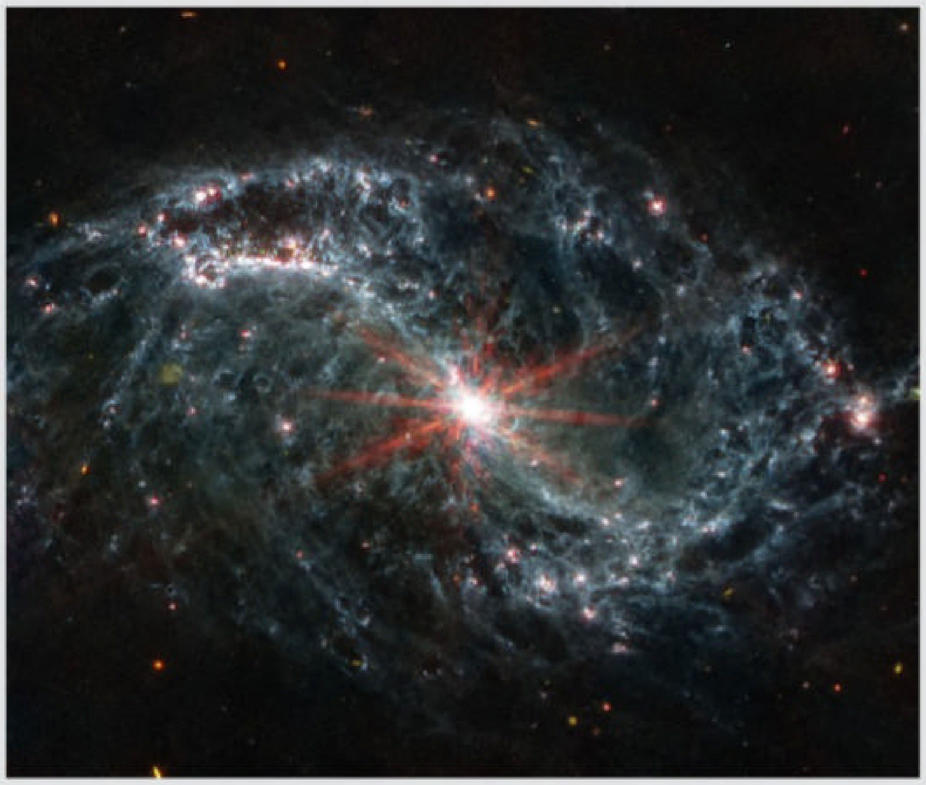
The light from these distant objects is not only faint, but it has been shifted to longer, redder wavelengths over the course of its awesome journey. Light from young stars is emitted at ultraviolet wavelengths; by the time it gets to the present-day universe, it is infrared light — JWST's specialty. Astronomers expected JWST to find more baby galaxies, adding to Hubble's haul. But it also found those six massive galaxies already formed some 500 million to 700 million years after the Big Bang.

EXAMINING ALL AVENUES

It is possible that astronomers have mischaracterized these galaxies. Obtaining spectra will give more detail about the galaxies' distance and makeup. The galaxies could be closer than they appear or smaller than calculated. They may not even be galaxies at all, but instead be supermassive black holes shrouded in dust and surrounded by glowing accretion disks.

However, there are currently six of these potential galaxy hulks where there should be none. "If even one of these galaxies is real, it will push against the limits of our understanding of cosmology," said study co-author Erica Nelson of the University of Colorado at Boulder in a statement. – KOREY HAYNES

Newborn stars carve out voids



SCIENCE: NASA, ESA, CSA, JANICE LEE (NOIRLAB); IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI)

This ghostly image of the spiral galaxy NGC 7496 reveals fine filaments of gas and dust interspersed with gigantic voids carved out by young, energetic stars. The resolution and sensitivity of the James Webb Space Telescope (JWST) enabled it to identify 67 new candidate star clusters within the galaxy, which is located some 24 million light-years away in the constellation Grus the Crane. NGC 7496 is one of 19 galaxies targeted by JWST for the Physics at High Angular resolution in Nearby Galaxies (PHANGS) collaboration, which seeks to better understand how interstellar gas and star formation affect the structure and evolution of galaxies. JWST's role in the project is to use its infrared vision to cut through the gas and dust that often surrounds newly formed stars and obscures them in optical wavelengths. In this case, JWST utilized its Mid-Infrared Instrument (MIRI), which is sensitive to wavelengths ranging from about 5 to 28 micrometers. The observations were published Feb. 16 in *The Astrophysical Journal Letters*. – JAKE PARKS

QUICK TAKES

HITTING THE BRAKES

Earth's solid inner core may be slowing its rotation so much that it could now be spinning slower than the mantle, an analysis of seismic data shows. This differential rotation between layers may be linked to changes in the planet's magnetic field and length of day.

ALEXA, FIND ALIENS

Astronomers have enlisted a deep-learning algorithm to comb radio data from the Breakthrough Listen project for signs of extraterrestrial intelligence. The AI turned up over 20,000 possible signals; researchers found eight to be "promising" and worthy of follow-up observations.

COSMOLOGICAL COUPLING

Measurements of black hole growth in elliptical galaxies could support a theory that black holes are the source of dark energy, the mysterious pressure driving the expansion of the universe. The theory suggests black holes are not singularities but instead enclose vacuum energy, the amount of which grows as the universe expands.

ROVER LIMITATIONS

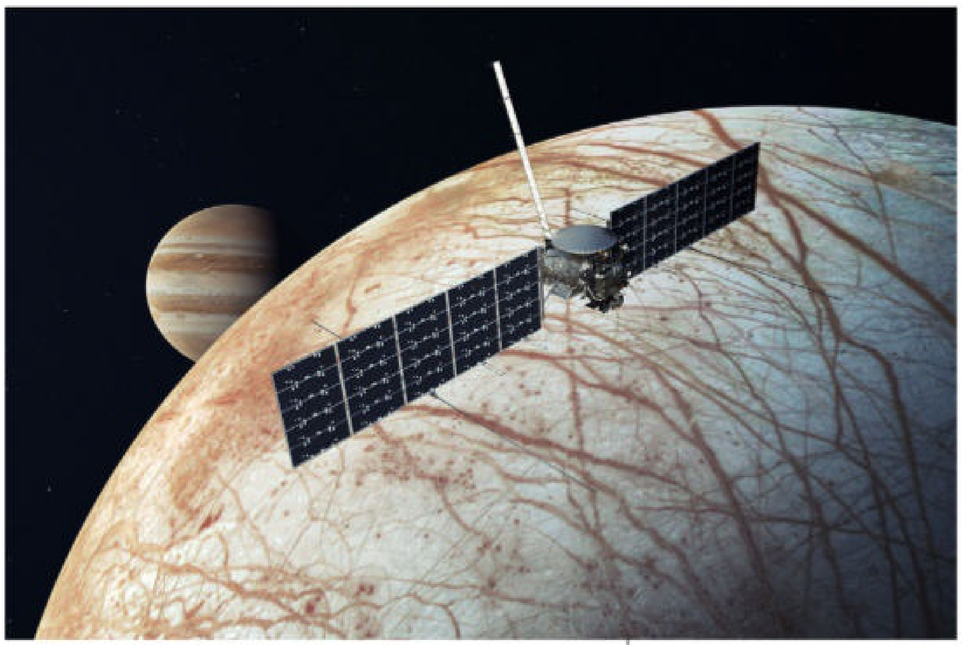
Researchers are questioning the ability of Mars rovers to detect traces of past life. Testing shows current and next-gen rover instruments are barely able to detect fossilized microorganisms in analogous desert environments on Earth, where we know such life flourishes.

CLIMATE MOONSHOT

Astronomers have calculated that it would be possible to halt climate change by firing dust from the Moon to the L1 Lagrange point to block sunlight from reaching Earth. In a statement, the team said they are not experts in climate change, just exploring options.

— MARK ZASTROW

New form of ice could exist on ocean moons



SETTING SAIL. NASA's Europa Clipper mission, scheduled to arrive at Jupiter in 2030, will scrutinize Jupiter's icy moon Europa, which is known to be covered in amorphous ice. NASA/JPL-CALTECH

CHEMISTS HAVE discovered a new form of ice, and their work may have major consequences for our understanding of the outer solar system.

Thanks to Earth's temperate conditions, the solid ice we're familiar with comes in one variety, where water molecules arrange themselves into an orderly crystalline structure. But there is another class of ice that does not contain repeated structures. This is called amorphous ice, and it is ubiquitous in the frigid realms of deep space, from molecular clouds to comets and icy moons.

BEARING IN MIND. The key to producing medium-density amorphous ice was to pulverize ultra-cold crystalline ice with small steel balls. CHRISTOPH SALZMANN

For decades, scientists have known of two kinds of amorphous ice: low-density and high-density. But recently, a team of chemists created a third kind, which they called medium-density amorphous (MDA) ice.

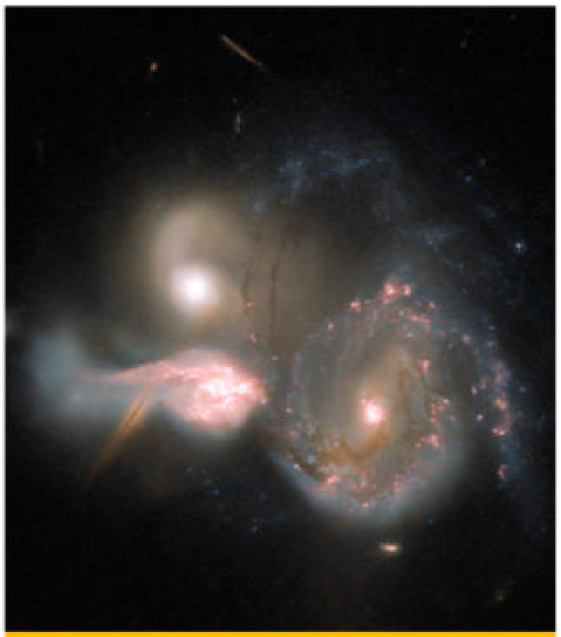
The team's process was simple: They put ice chilled to –340 degrees Fahrenheit (–255 degrees Celsius) into a container with small steel balls and then used a machine to vigorously shake the container back and forth 20 times per second.

"We shook the ice like crazy for a long time and destroyed the crystal structure," said Alexander Rosu-Finsen of University College London in a press release. "Rather than ending up with smaller pieces of ice, we realized that we had come up with an entirely new kind of thing, with some remarkable properties." Rosu-Finsen was the first author of a paper on the new form of ice, published Feb. 2 in the journal *Nature*.

While low-density amorphous ice is less dense than liquid water and high-density amorphous ice is more dense, MDA ice has nearly the same density as liquid water. It's as if water has simply become frozen in time rather than crystalizing to conventional ice.

The researchers also found that when they warmed up MDA ice, it turned back into a regular crystal lattice, releasing a surprising amount of energy. This could have huge implications for the nature of frozen moons like Jupiter's Europa and Ganymede.

Those worlds have thick ice shells surrounding globe-spanning oceans of liquid water — prime places to search for signs of past or present life. If MDA ice is present there, shifts in temperature could cause it to suddenly crystalize, triggering tectonic motions in the moons' giant ice sheets and completely altering the boundary of ice and liquid in their interiors. –PAUL SUTTER

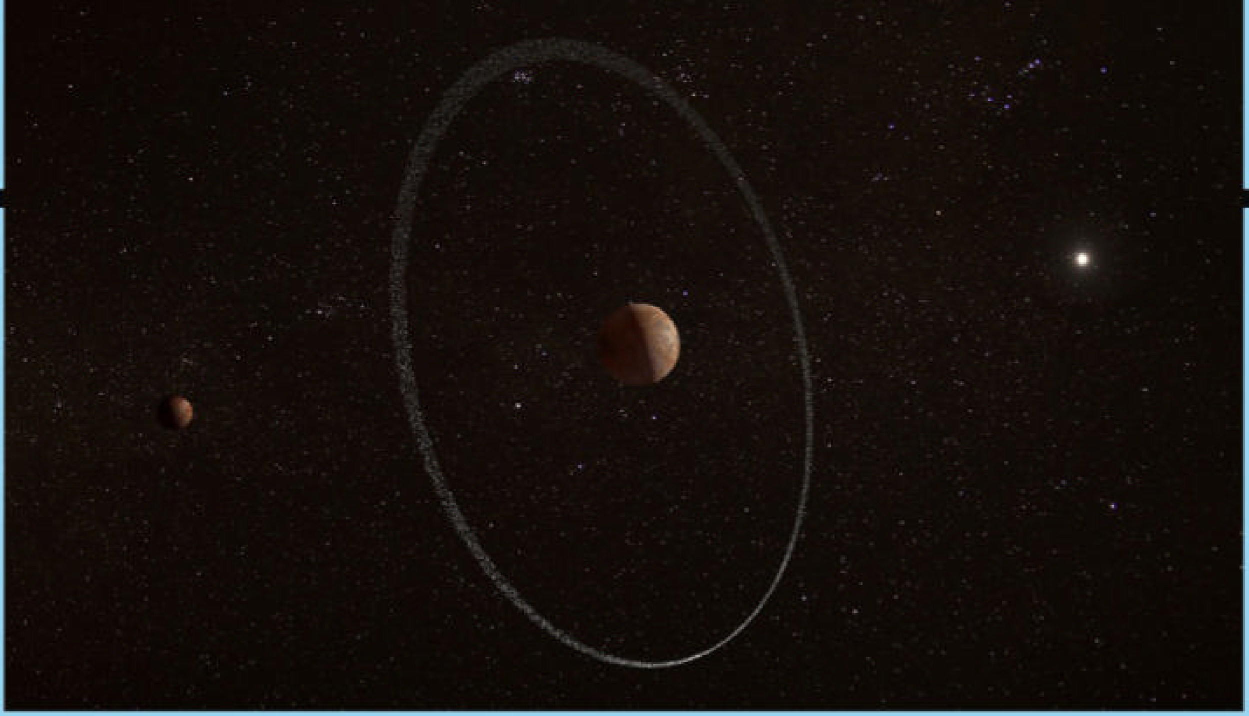


ESA/HUBBLE & NASA, M. SUN

BRIGHTER DAYS AHEAD

This trio of galaxies is undergoing a slow-motion pileup that will erase their beautiful spiral structures. But they will emerge from this encounter as a bright elliptical galaxy that will dominate the region around it. Known collectively as SDSSCGB 10189, the three galaxies lie in the constellation Boötes, roughly 1 billion light-years away from Earth. In this image taken by the Hubble Space Telescope, their spiral arms are being flung around and distorted by the galaxies' mutual gravitational forces. Astronomers suspect that when they are fully merged, the resulting elliptical will be an example of the class of galaxies known as Brightest Cluster Galaxies — the brightest and most massive galaxies in a given cluster. This Hubble observation was made to better understand how these galaxies form. –M.Z.

QUAOAR HAS A RING THAT SHOULDN'T BE THERE



TOO FAR OUT. Quaoar's ring, seen in this artist's impression, is located at twice the dwarf planet's Roche limit, the theoretical distance from a body beyond which rings should not form. ESA

ASTRONOMERS HAVE found that the 700-mile-wide (1,100 kilometers) dwarf planet Quaoar, which resides in the outer solar system, sports a strange ring. But according to researchers, this lumpy ring of material is so far from the icy world's surface that theory says it should have formed into a moon instead.

"At the end of the day, this ring is not where we expect it to be," Bruno Morgado, an astronomer at the Federal University of Rio de Janeiro in Brazil and lead author of the new study, tells *Astronomy*. The paper detailing the discovery of Quaoar's ring was published Feb. 8 in *Nature*.

Scientists spotted Quaoar's unusual ring, which they describe as "clumpy," using the European Space Agency's Cheops space telescope, as well as multiple ground-based observatories. The researchers were able to closely study Quaoar because it passed in front of four different background stars between 2018 and 2021, each time revealing clues about its size and immediate surroundings.

Pretty as planetary rings may be, creating them involves a fair bit of gravitational gore. Dense systems like the rings around Saturn form inside what's called the Roche limit. This is the radius within which a body's gravity is strong enough to rip apart objects that stray too close, smearing the resulting debris into rings.

Rings shouldn't exist far beyond an object's Roche limit, which is determined by the body's size and density — but Quaoar doesn't seem to have gotten the memo. Its newly discovered ring orbits twice as far as Quaoar's Roche limit, meaning the ring should have coalesced into a tiny moonlet within just a few decades.

"Of course, it could be that we are looking at [Quaoar] exactly in this mid-time between the ring becoming a satellite," says Morgado. But "it's very unlikely ... that we are exactly at the right time to be able to see this happening. So, it's more probable that the ring is indeed stable."

At this point, only two other small bodies in the solar system, Haumea and Chariklo, are known to host rings. However, Morgado expects that to change in the future.

"We believe that many more rings are [out] there," says Morgado. "We need to keep observing, and also to look far, far away from the bodies just to see if there is something there. Because the Roche limit may not be the limit anymore."

— ELISE CUTTS

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40 million

The number of bowls of crackling Rice Krispies needed to match the volume of the Artemis 1 rocket launch at a distance of 3.1 miles (5 km), according to recently published noise measurements.

Huge cosmic map offers rich rewards

LOVOCCS/DESI LEGACY IMAGING SURVEY/KPNO/NOIRLAB/NSF/AURA; IMAGE PROCESSING: T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF'S NOIRLAB, JEN MILLER, M. ZAMANI & D. DE MARTIN (NSF'S NOIRLAB)

Abell 3158 is a massive galaxy cluster some 825 million light-years away, teeming with island universes. But the image at right is just one sliver of the Dark Energy Spectroscopic Instrument (DESI) Legacy Imaging Survey, the largest 2D map of the sky ever assembled, which combines six years of images from Kitt Peak National Observatory in Arizona and Cerro Tololo Inter-American Observatory in Chile. With a recent 10th data release, the map now covers some 20,000 square degrees and includes more than 1 billion galaxies. It has provided 40 million targets for a new project, the DESI Spectroscopic Survey, to observe galaxies and clusters at different distances — and thus varying times in the past. Doing so will help uncover the effects of dark energy on the expansion of the cosmos over time. The survey data are publicly available, providing a rich resource for anyone who wants to study our universe. — A.K.

Milky Way stars found nearly halfway to Andromeda Galaxy

A SLEW OF NEWFOUND STARS LINGERING in the fringes of our galaxy are so far away, they could redefine the outer limits of the Milky Way. The most distant of these stars is more than 1 million light-years from the galactic center. That's almost halfway to our largest neighbor, the Andromeda Galaxy, which is some 2.5 million light-years away.

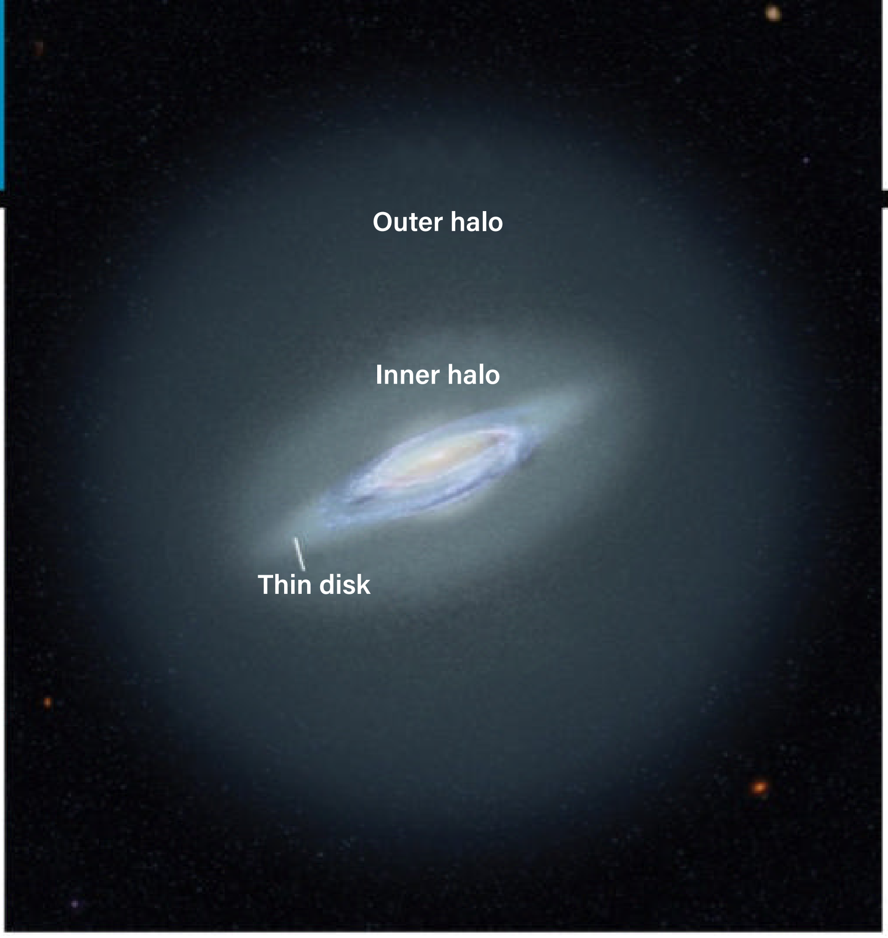
The stars identified in this study — a class of variables known as RR Lyrae stars — were plucked from a survey by the Canada-France-Hawaii Telescope on Mauna Kea. The dataset focused on the Virgo Cluster of galaxies, which lies outside our own Local Group. But the Milky Way stars were waiting in the foreground of the data, the researchers say. The results were presented in January at the 241st meeting of the American Astronomical Society in Seattle, Washington.

RR Lyrae stars are valuable to astronomers because they all have roughly the same mass and luminosity — and also exhibit characteristic pulsations, resulting in predictable variations in brightness that make them easy to identify. This makes RR Lyrae stars an excellent type of distance indicator that astronomers call a standard candle. Because their intrinsic brightness is known, it is easy to determine their distance based on how faint they appear to be.

The 208 RR Lyrae stars detected by the team are located in the Milky Way's outer halo and lie between about 65,000 to 1.05 million light-years from the galactic center. This is consistent with models that predict the outer halo should extend that far, Yuting Feng, a doctoral student at the University of California, Santa Cruz, who led the study, tells *Astronomy*. "So that's an important result."

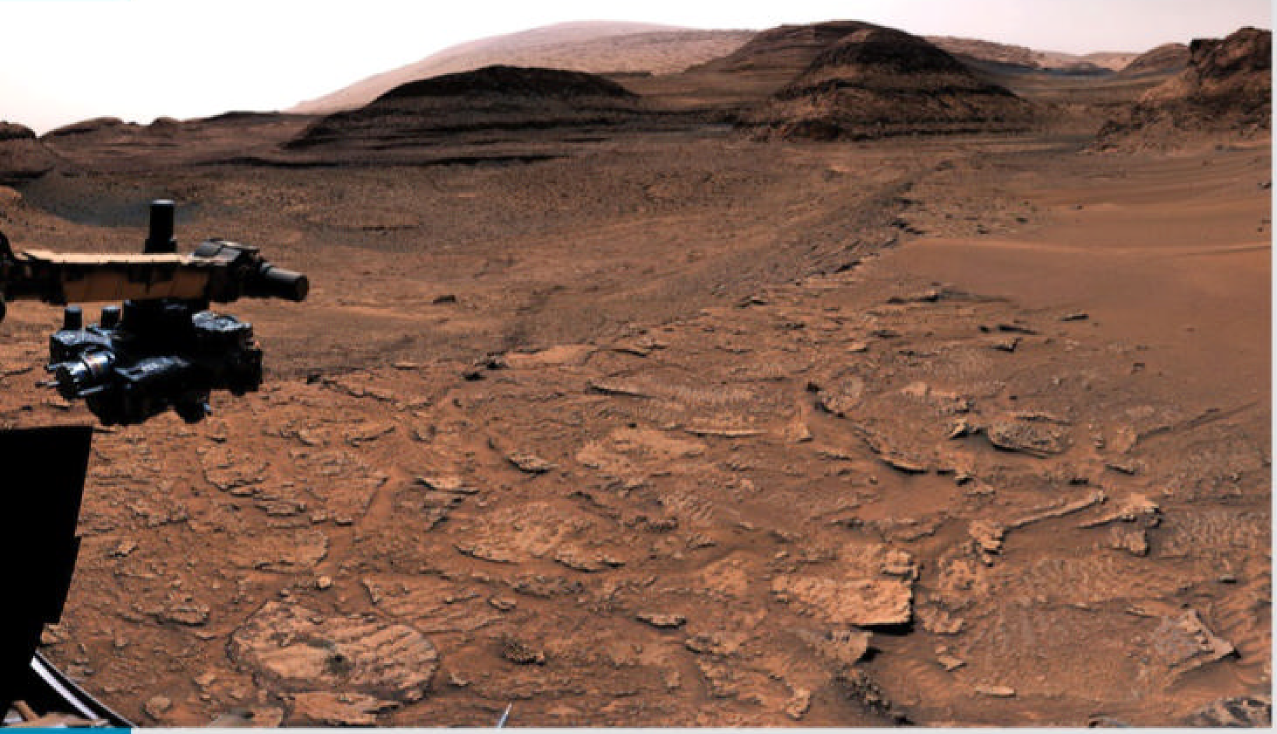
But those same models predict that beyond 1 million light-years, stars should get much sparser. The fact that Feng and his colleagues have been able to see so many stars near this theoretical border suggests that this dip in stellar density might occur farther out. If that's the case, there's a chance that the halos of the Milky Way and Andromeda already overlap. "It challenges the notion that galaxies are islands with big, empty space between them," Raja GuhaThakurta, Feng's advisor, says.

"I won't be surprised if there are a few dozens of stars which are being contested by the two galaxies," Feng adds. —J.P.



URBAN SPRAWL. The Milky Way's outer halo extends some 1 million light-years from the core of our galaxy — and a few newfound stars are living right at the theoretical outskirts. NASA, ESA, AND A. FEILD (STSCI)

WATER-MADE RIPPLES SPOTTED ON MARS



NASA/JPL-CALTECH/MSSS

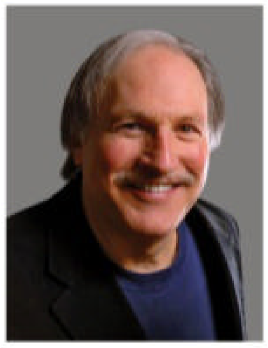
NASA's Curiosity rover has stumbled upon the clearest signs yet of an ancient martian lake: fossilized ripples on the ground. The distinctive texture is a preserved snapshot of a sandy lakebed stirred up by waves sloshing across the surface of the water. "This is the best evidence of water and waves that we've seen in the entire mission," said Ashwin Vasavada, Curiosity's project scientist at NASA's Jet Propulsion Laboratory, in a statement. "We climbed through thousands of feet of lake deposits and never saw evidence like this." The region of Mount Sharp that the rover is currently exploring is what geologists call a sulfate-bearing unit — an area rich with salty minerals that may have been left behind as water dried up across the landscape. —M.Z.

Astronomy for slobs

When is too messy *really* too messy?

Cleaning your telescope's mirror can feel like a process requiring highly trained engineers, like this pair removing particulates from one of JWST's mirrors. But do we really *need* to clear that dust away?

NASA/CHRIS GUNN



BY BOB BERMAN

Bob's recent book, Earth-Shattering *(Little, Brown and Company, 2019), explores the greatest cataclysms that have shaken the universe.*

One appeal of astro-observing is that we're inspecting a vast realm where nothing is sloppily arranged or in need of vacuuming — though the Moon's southern highlands are admittedly a crowded mess, with many craters piled partially atop others.

Then there's Mars, whose dry and dusty landscape has terminated numerous martian missions, albeit long past their expected use-by date. Dust caked on the solar panels of the InSight lander recently brought that mission to an end, and while the Spirit and Opportunity rovers were lucky enough to have dust devils give their solar panels quick and timely scours, dust eventually did them both in.

But rather than sloppiness imposed by nature, let's talk about whether it matters if you're a Class 3 slob after you spent your savings on a telescope. It's fine not to wax and polish our telescope tubes, but how much neglect constitutes negligence?

Generally, I'll only get rid of observatory objects that move of their own volition, like wasps and snakes. But what about, say, fallen leaves? Do they do any harm other than providing an odd, crunchy soundtrack when stepped on? Leave them until they're ankle deep!

The classic telescope cleanliness issue is tolerance to dust, which is highly visible on objective lenses and mirrors. Remembering those martian mishaps, is earthly dust a similar threat? When my 12.5-inch f/6 mirror gets really dusty — like around now, a quarter-century since I last cleaned it — is it finally time?

The process initially sounds delicate but not overly complicated. Place the mirror shiny side up on a towel in a kitchen sink, letting a stream of water run over it, and lightly swirl cotton balls over it after they've been soaked in a detergent such as Tide. But then comes the Ph.D.-necessitating issue of how to dry it. That's where art and science meet, since proper drying determines whether you're left with image-marring sleeks or a perfect mirror that can be safely ignored until the next solar totality darkens Walt Disney World in 2045.

What about eyepieces? Your Type A, never-miss-a-spot-while-shaving astronomers have them arranged by focal length in a dustproof box. At the other extreme are those who stuff them in their jacket pocket. Is this bad? Pockets let lint hit the lenses, but you can blow it off easily enough. And the field lens is so deeply recessed that it won't be struck by the metal parts of other eyepieces. So maybe it's okay to wear your optics — at least, the cheap orthoscopic eyepieces with tiny eye lenses.

Fingers on lenses are another matter. They truly don't mix — and we're not just being fussy, like those who feel the need to use a knife and fork to eat burgers or pizza. It's not a mere matter of appearance: The oils on our hands should never touch the optics.

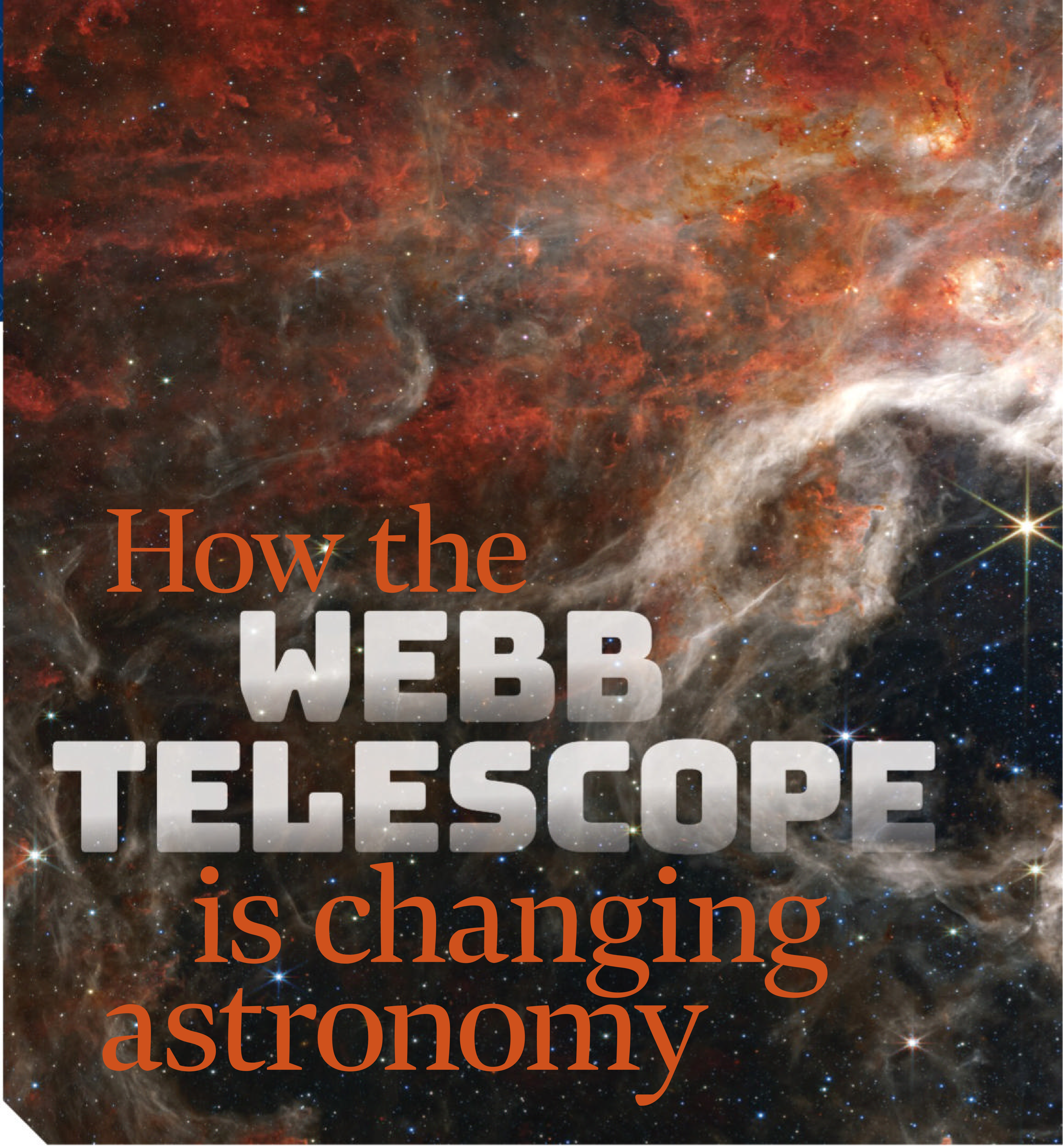
In truth, dust can usually be ignored.

But dust looks much worse than it is because it rarely impairs a scope's performance. So, should we be laissez-faire about it? The question might take you back to age 12, when your grandmother insisted that you stop tossing your socks on the floor at bedtime while your instincts told you that socks belong on the floor during hours of darkness. In truth, dust can usually be ignored.

And being laid back while probing infinity has its own benefits. Nobel Prizes have been awarded for accidental discoveries and those made by goof-offs. Nothing's inherently wrong with slobbery. The true bottom line, and one of astronomy's fundamental appeals, is that the cosmos is OK with its denizens being true to themselves.

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman**

How the WEBB TELESCOPE is changing astronomy



With its penetrating infrared gaze, JWST is revealing planets, stars, and more in a whole new light. **BY RICHARD TALCOTT**

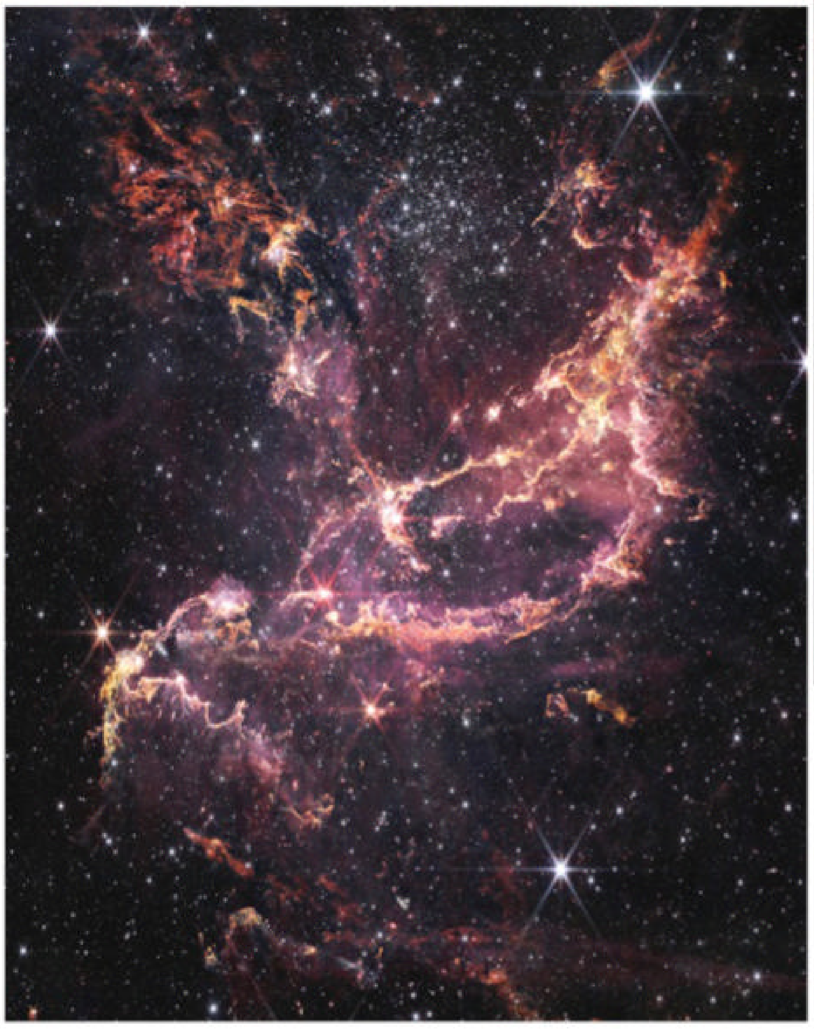
WHEN AN ARIANE 5 ROCKET lifted off from French Guiana on Christmas Day 2021, it carried a cargo of dreams: the James Webb Space Telescope (JWST). Those dreams belonged to astronomers hoping to peer farther into space than ever before, to a time when the first galaxies formed; to penetrate dust clouds to witness the birth of stars; and to probe the atmospheres of exoplanets to see if they might support life. After more than a year in space, JWST is starting to turn those dreams into reality.

The newest space telescope comes with significant advantages

The massive blue-white stars at the center of the Tarantula Nebula (NGC 2070) in the Large Magellanic Cloud have carved a huge cavity into their gaseous surroundings. In this JWST view, hotter gas glows yellow-white and cooler gas appears more rust-colored. NASA/ESA/CSA/STSCI

over any previous mission. First and foremost is its size: JWST features a 6.5-meter mirror composed of 18 gold-plated hexagonal segments. This colossus gathers more than six times as much light as the Hubble Space Telescope's 2.4-meter mirror, so it can record light from objects six times faster than its predecessor.

But JWST's sensitivity to infrared light is the real game-changer. The space telescope can view wavelengths from 0.6 to



JWST reveals fine details in the bright star-forming region NGC 346, which lies 200,000 light-years from Earth in the Small Magellanic Cloud. Astronomers will use such relatively nearby objects, which JWST sees in unprecedented detail, to better understand similar objects that reside much farther away. NASA/ESA/CSA/STSCI/A.PAGAN (STSCI)

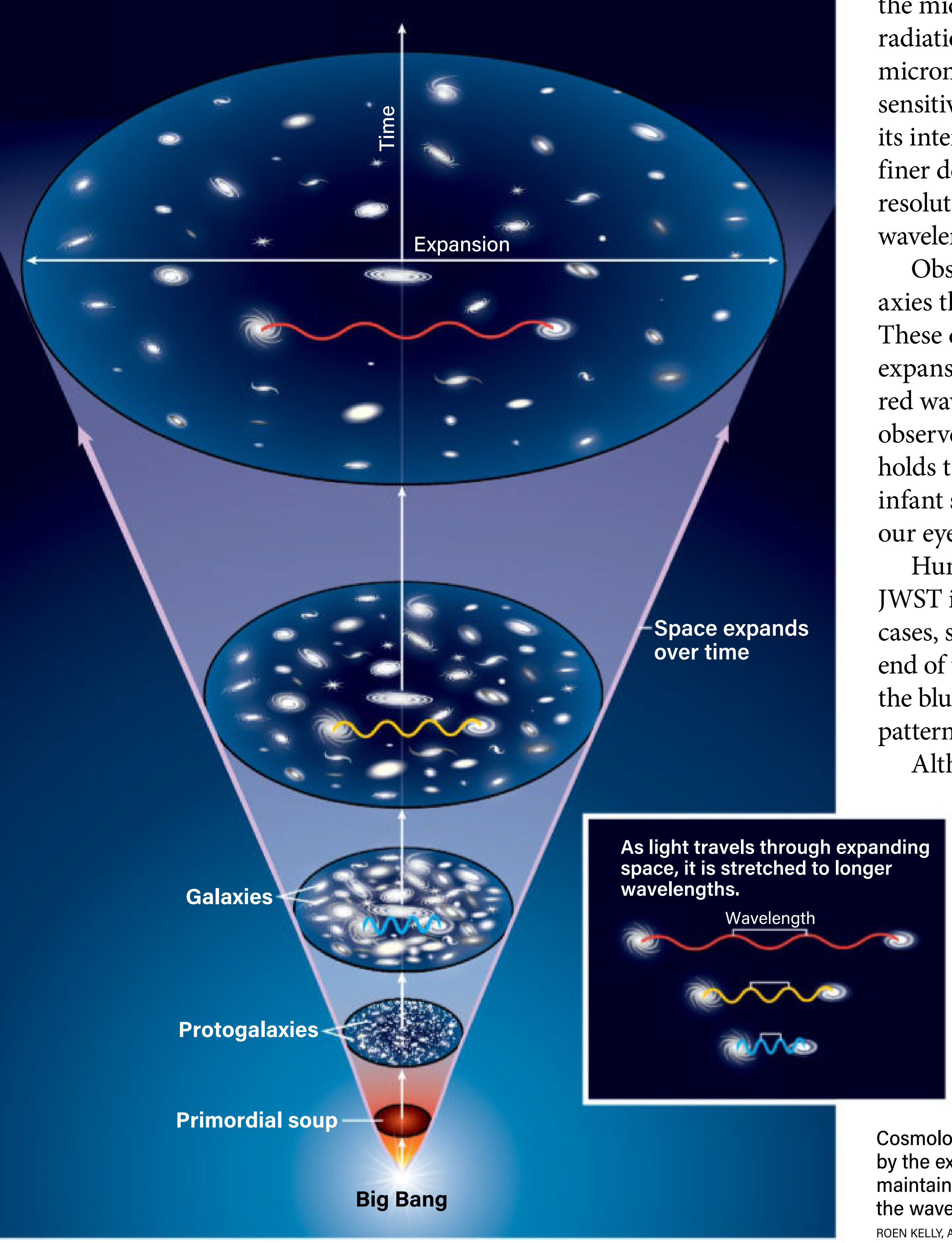
28.5 micrometers, from the red end of the visible spectrum to the mid-infrared. Hubble's optics are optimized to record radiation from 0.09 micrometer (in the ultraviolet) to 2.5 micrometers (in the near-infrared), with the majority of its sensitivity centered on visible light. Perhaps surprisingly, in its intended infrared domain, JWST generally won't resolve finer details than Hubble achieves in optical light: Although resolution increases with mirror size, it also diminishes with wavelength.

Observing in the infrared allows astronomers to see galaxies that existed less than a billion years after the Big Bang. These distant objects emit ultraviolet and visible light, but the expansion of the universe shifts this radiation to longer infrared wavelengths. Peering into the infrared is the only way to observe these young galaxies from Earth's vicinity. The same holds true for newly forming stars. The dust that envelops infant suns scatters visible light, hiding what lies within from our eyes, but it lets infrared radiation largely pass through.

Humans cannot see infrared radiation. So, the colors in JWST images don't match what the eye would see. In many cases, scientists map longer infrared wavelengths to the red end of the visible spectrum and shorter wavelengths toward the blue, mimicking how the eye operates. But sometimes this pattern is altered to show details in a more revealing light.

Although JWST launched in late 2021, it took the space observatory 29 days to reach its home orbiting the L2 Lagrange point about 930,000 miles (1.5 million kilometers) from Earth, and an additional five months for scientists and engineers to get the telescope ready for its debut. Most of the results so far come from early-release science programs and proposals from the first cycle of science operations (Cycle 1). Read on to explore some of the telescope's most exciting early finds.

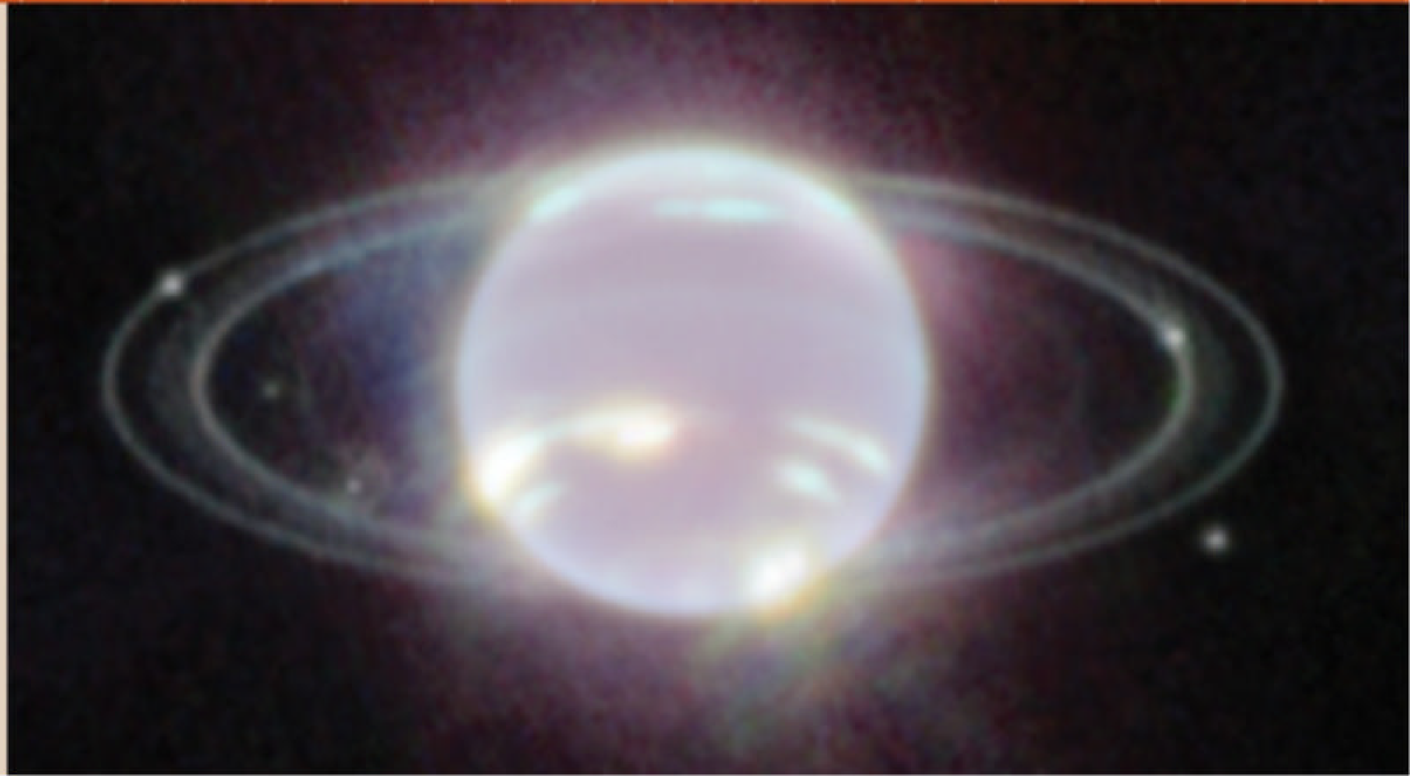
WHAT IS COSMOLOGICAL REDSHIFT?



Cosmological redshift is the stretching of light to longer (redder) wavelengths by the expansion of the universe itself. As space expands, stars and galaxies maintain their size, but the distance between them grows. This stretches out the wavelength of light as it travels through our expanding universe. *ASTRONOMY:* ROEN KELLY, AFTER NASA/ESA/L. HUSTAK (STSCI)

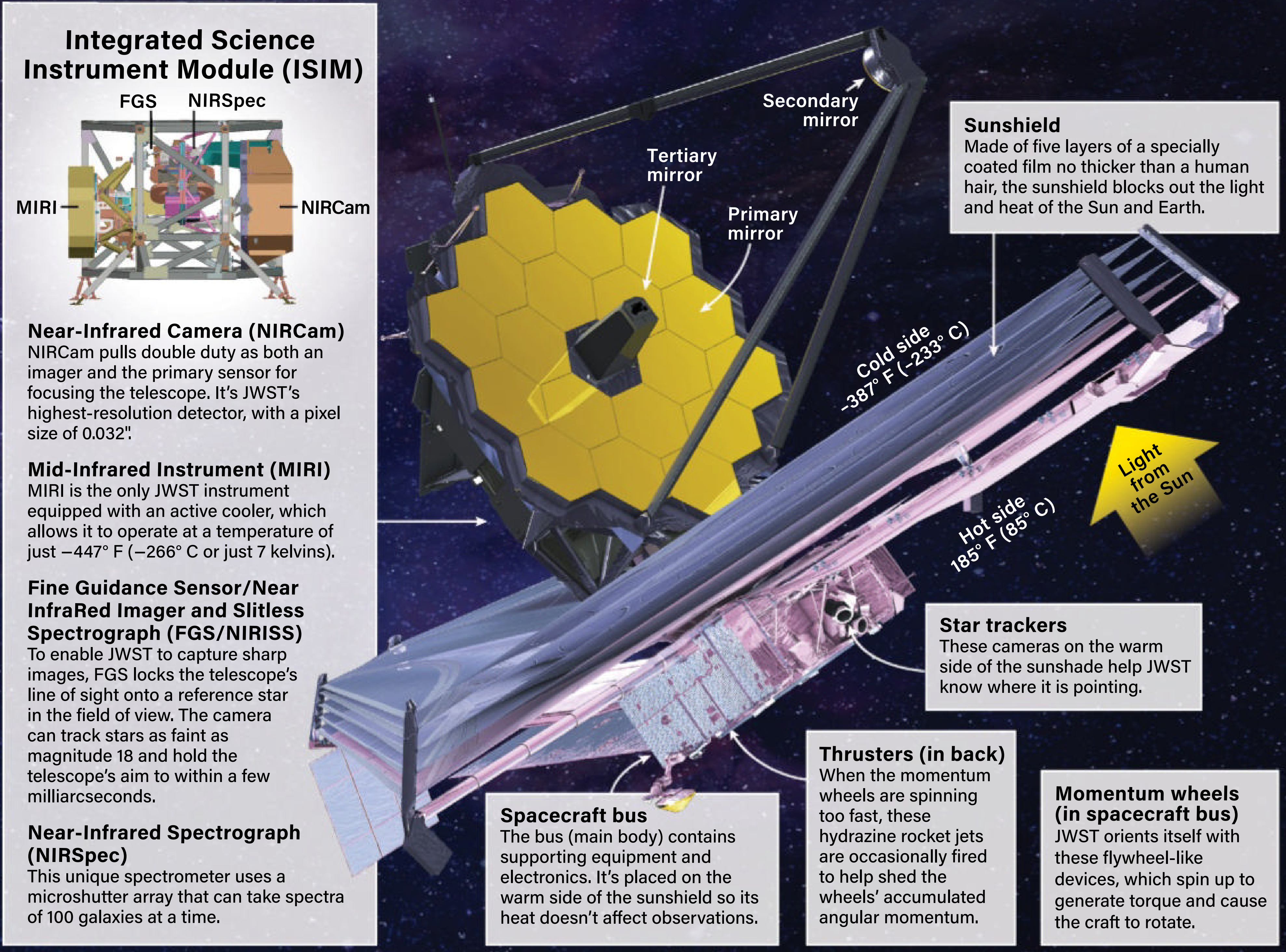
CLOSE TO HOME

DESPITE ITS FOCUS on distant galaxies and star formation, JWST is an all-purpose observatory. Its powerful infrared eye sees details in solar system objects beyond the reach of conventional telescopes. Early observations include studying cloud belts on the gas



Neptune and its complex ring system came into better focus with JWST than at any time since Voyager 2 flew past in 1989. Most of the planet appears dark because methane gas absorbs the near-infrared light the telescope detects. The bright streaks and spots are clouds of methane ice that reflect incoming sunlight. NASA/ESA/CSA/STSCI

THE JAMES WEBB SPACE TELESCOPE



Near-Infrared Camera (NIRCam)
NIRCam pulls double duty as both an imager and the primary sensor for focusing the telescope. It's JWST's highest-resolution detector, with a pixel size of 0.032".

Mid-Infrared Instrument (MIRI)
MIRI is the only JWST instrument equipped with an active cooler, which allows it to operate at a temperature of just –447° F (–266° C or just 7 kelvins).

Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph (FGS/NIRISS)
To enable JWST to capture sharp images, FGS locks the telescope's line of sight onto a reference star in the field of view. The camera can track stars as faint as magnitude 18 and hold the telescope's aim to within a few milliarcseconds.

Near-Infrared Spectrograph (NIRSpec)
This unique spectrometer uses a microshutter array that can take spectra of 100 galaxies at a time.

Sunshield
Made of five layers of a specially coated film no thicker than a human hair, the sunshield blocks out the light and heat of the Sun and Earth.

Star trackers
These cameras on the warm side of the sunshade help JWST know where it is pointing.

Spacecraft bus
The bus (main body) contains supporting equipment and electronics. It's placed on the warm side of the sunshield so its heat doesn't affect observations.

Thrusters (in back)
When the momentum wheels are spinning too fast, these hydrazine rocket jets are occasionally fired to help shed the wheels' accumulated angular momentum.

Momentum wheels (in spacecraft bus)
JWST orients itself with these flywheel-like devices, which spin up to generate torque and cause the craft to rotate.

ASTRONOMY: ROEN KELLY

and ice giant planets; tracking cloud formations on Saturn's largest moon, Titan; exploring Pluto's climate; and probing many of the smaller asteroids and trans-Neptunian objects that populate the outer solar system.

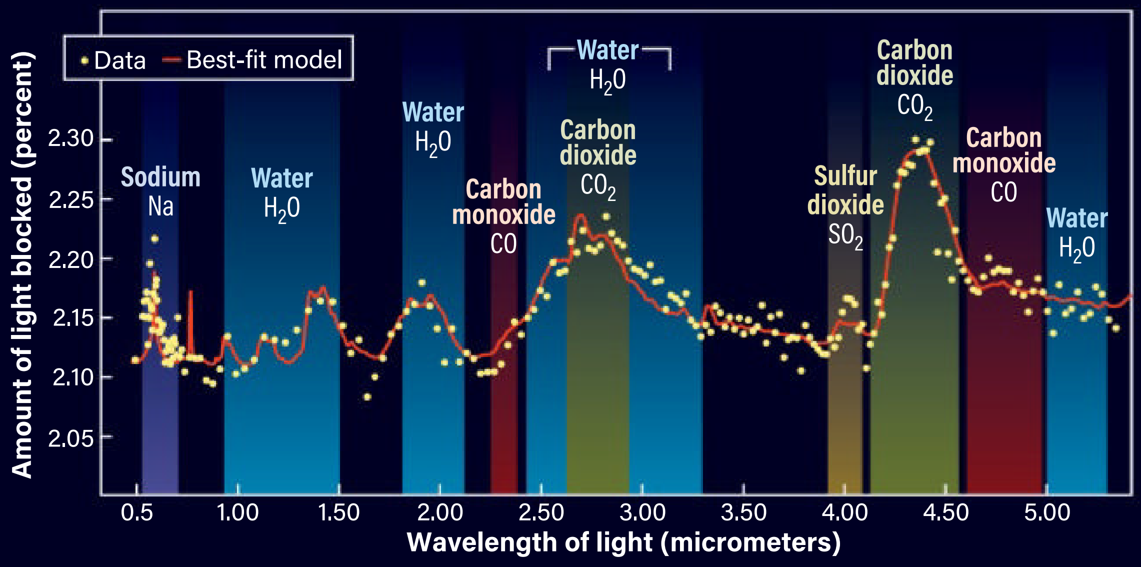
JWST even observed the asteroid moonlet Dimorphos in September when NASA's Double Asteroid Redirection Test (DART) slammed into it. The impact slightly changed the object's orbit around its parent body, Didymos, helping the space agency assess its ability to alter the course of potentially hazardous asteroids that could cross Earth's path.

It's not far-fetched to think of the space telescope as a planetary weather satellite for the entire solar system. Our last close-up views of Saturn came just before the Cassini spacecraft crashed into the ringed planet in September 2017. And no spacecraft has visited Uranus or Neptune since Voyager 2 flew past them in the latter half of the 1980s. But JWST can view storm systems on these worlds in exquisite detail.

Neptune came under the telescope's watchful eye last July. Most of the ice giant's visible surface looks dark because methane gas in its atmosphere absorbs near-infrared light. But several clouds of methane ice gleam brightly and a hint of the planet's global circulation appears as a thin line tracing the equator. This circulation powers Neptune's storms and powerful winds, which blow faster than those of any other planet. JWST also delivered the sharpest views of Neptune's rings since Voyager 2 visited the world in 1989.

HONEYCOMB: *ASTRONOMY* STAFF

OTHER WORLDS



WHAT'S IN THE ATMOSPHERE OF WASP-39 B?

Above is a spectrum taken by JWST's NIRSpec to unveil the chemical composition of the scorching-hot exoplanet WASP-39 b. The telescope's sensitivity to near-infrared light reveals the signatures of carbon dioxide, carbon monoxide, sodium, sulfur dioxide, and water. Other instruments also discovered potassium. *ASTRONOMY*: ROEN KELLY, AFTER NASA/ESA/CSA/J. OLMSTED (STSCI)

EVEN AS PLANETARY SCIENTISTS work to reveal our solar system's many tantalizing secrets, the over 5,000 known exoplanets in our galaxy remain a mystery. While we typically know their orbits and often their sizes and masses, most other information lies beyond the reach of Earth-based telescopes and even Hubble. But JWST has already started to change the status quo.

How important are exoplanets to JWST scientists? They allocated nearly one-quarter of observing time during Cycle 1 to the study of these worlds and the materials that form them.

Although not designed to discover exoplanets, JWST has confirmed one around the star LHS 475, a red dwarf located 41 light-years from Earth in the constellation Octans. NASA's Transiting Exoplanet Survey Satellite (TESS) hinted that this star might harbor a planet, but it took the new space telescope to confirm the minuscule dip in brightness caused by the planet crossing in front of, or transiting, the star's disk. The planet appears to be rocky, with a diameter just 1 percent smaller than Earth, though the resemblance to our home world stops there. It orbits its sun in only two days and boasts a temperature a few hundred degrees warmer than Earth.

However, JWST's real strength comes from its ability to analyze the atmospheres of exoplanets. To accomplish this, the telescope must observe transits with its powerful spectrographs. As a planet passes between Earth and its host star, its atmosphere filters out some wavelengths of the starlight. Because every atom and molecule has a distinct spectral fingerprint, this allows astronomers to study the chemical makeup of these worlds.

Most of the molecules that interest exoplanet researchers lie in the infrared part of the spectrum. While Hubble could tease scientists with its observations, JWST will satisfy their appetites.

The observatory's first exoplanet target was WASP-39 b, a hot gas giant planet orbiting a Sun-like star 700 light-years away in the constellation Virgo. JWST's superb resolution revealed water, sulfur dioxide, carbon monoxide, sodium, potassium, and — for the first time ever in any exoplanet — carbon dioxide. The planet glows at a temperature of 1,650 degrees Fahrenheit (900 degrees Celsius) not because of a runaway greenhouse effect, but because it orbits just 4.52 million miles (7.27 million km) from its star. (In comparison, Mercury orbits nearly 36 million miles [57.9 million km] from the Sun.)

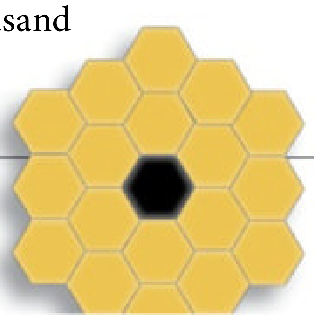
PEERING INSIDE STELLAR NURSERIES

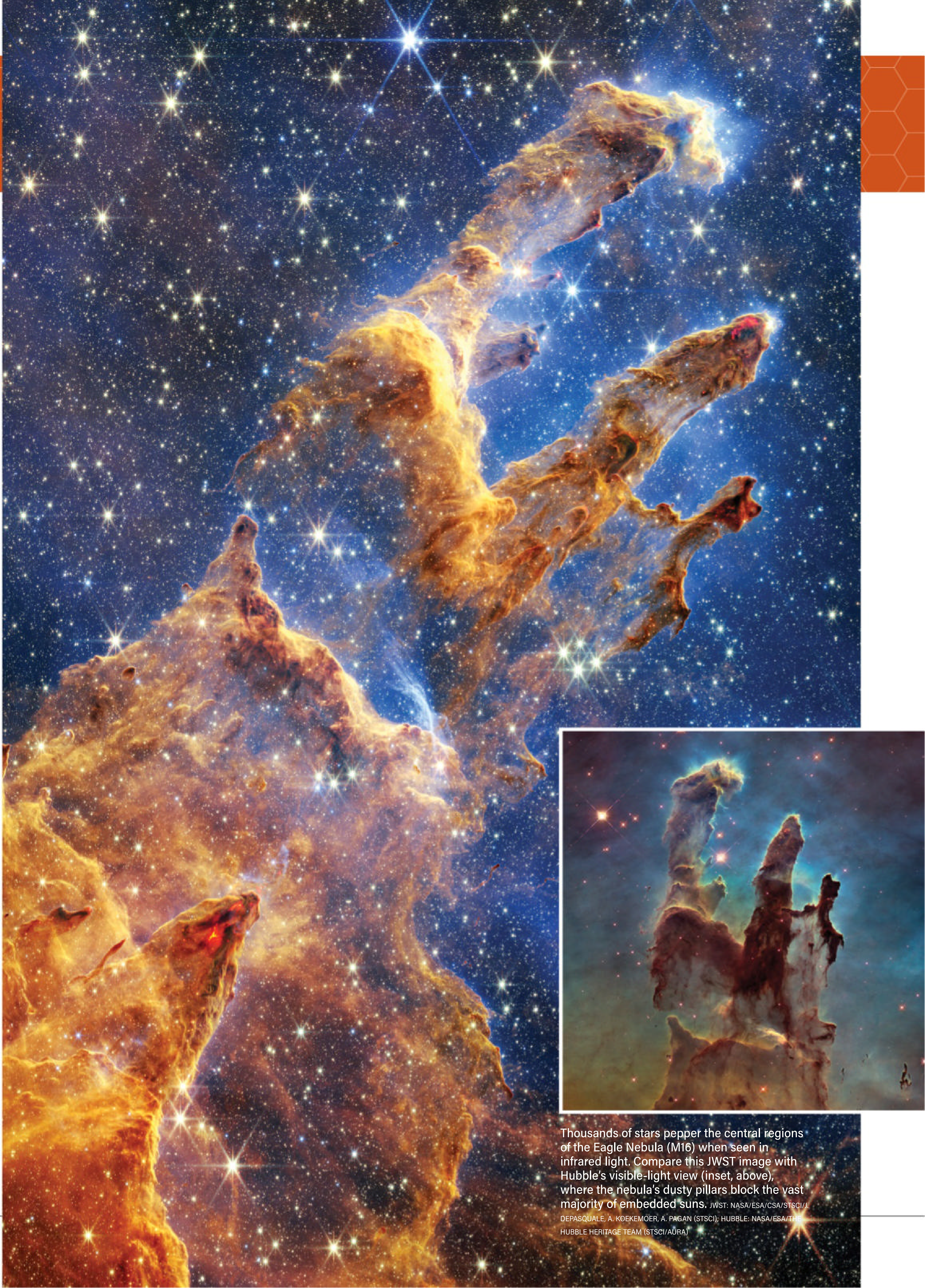
PLANETS AND THEIR HOST STARS all form inside the gas- and dust-rich stellar incubators astronomers call nebulae. But these clouds — as beautiful as they may be — cloak the vital activities happening within, at least in visible light. JWST's infrared vision has started to open up these environments.

One of its first targets was a small portion of the Eagle Nebula (M16) in the constellation Serpens, which Hubble made famous in 1995. The dramatic "Pillars of Creation" image was ranked among *TIME* magazine's list of the 100 most influential photos of all time. JWST captured an equally stunning view of this iconic star-forming region, which resides 6,500 light-years from Earth.

Where Hubble saw mostly opaque dust and cold gas, JWST revealed many stars already emerging from their natal cocoons. Most of these newborn stars appear outside the dark pillars and reveal themselves by their diffraction spikes, a feature of images taken with reflecting telescopes like JWST.

These infant suns have had time to ignite nuclear fusion in their core and become full-fledged stars. But JWST uncovered even younger objects known as protostars still pulling gas and dust from their surroundings. Such youngsters periodically spew jets of material that collide with their dense surroundings and cause them to radiate. The best examples show up as bright red glows near the tips of the two lower pillars. Astronomers estimate the protostars are just a few hundred thousand years old.





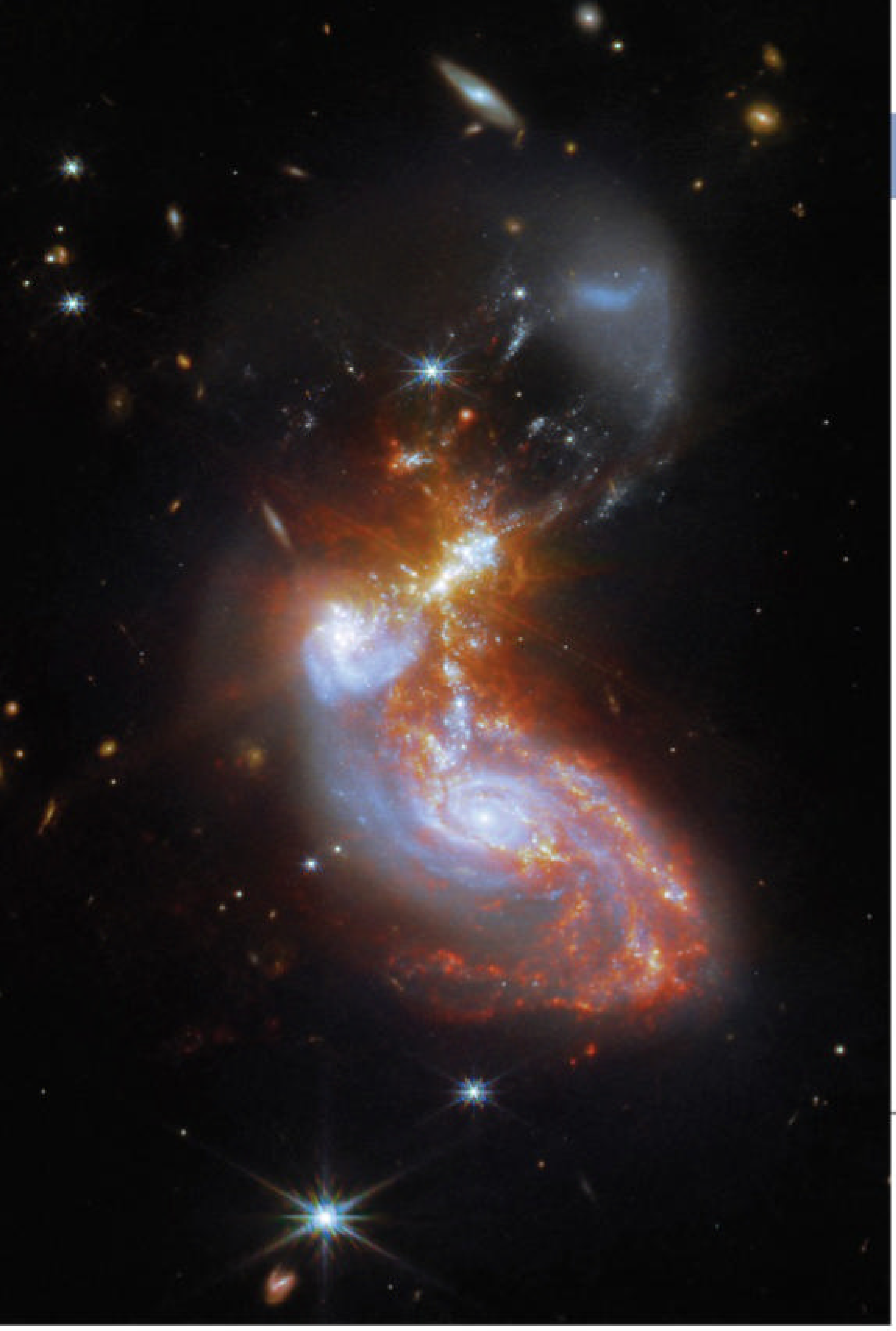
Thousands of stars pepper the central regions of the Eagle Nebula (M16) when seen in infrared light. Compare this JWST image with Hubble's visible-light view (inset, above), where the nebula's dusty pillars block the vast majority of embedded suns. JWST: NASA/ESA/CSA/STSCI/J. DEPASQUALE, A. KOEKEMOER, A. PAGAN (STSCI); HUBBLE: NASA/ESA/THE HUBBLE HERITAGE TEAM (STSCI/AURA)

BEYOND THE MILKY WAY

STAR FORMATION OCCURS throughout the universe, of course, and JWST scientists have been keen to explore its many expressions outside our galaxy. Two key sites lie within our Local Group. The Large and Small Magellanic Clouds, the two most massive satellite galaxies of the Milky Way, play a huge role in deciphering the universe.

That's because the amount of metals — elements heavier than helium cooked up within massive stars — in the two galaxies turns out to be about half that in the Milky Way. These conditions mimic those that existed when the cosmos was just 2 billion or 3 billion years old and galaxies were churning out stars at their highest rate. The fireworks during this so-called cosmic noon shaped the galaxies at that time and continue to influence the galaxies we see today.

No feature in the Magellanic Clouds comes closer to mirroring these chaotic times than the large cloud's Tarantula Nebula (NGC 2070). (For more on



The gravitational interaction between the two galaxies that make up II Zw 96 has distorted their shapes and drawn out tendrils of gas and dust that seem to connect their cores. The ongoing merger has also triggered a burst of star formation, making the pair especially bright at infrared wavelengths. ESA/WEBB/NASA/CSA/L. ARMUS, A.S. EVANS

TO THE EDGE

IN MANY CASES, observations of close objects allow researchers to make better sense of more distant ones. Planets in our solar system inform studies of exoworlds just as star formation in the Magellanic Clouds sheds light on similar regions in the distant universe. In much the same way, studying interacting galaxies leads directly to the ultimate goal of understanding the turbulent early days of the cosmos.

But while nearby regions can often serve as analogues for older, more distant environments, JWST was designed to directly observe ancient galaxies formed at the dawn of the cosmos — and astronomers have relished testing this capability.

One of JWST's first images — and the first one publicly released — was a deep-field photo of the galaxy cluster SMACS 0723 in the southern constellation Volans. The exposure took 12.5 hours, compared with weeks for Hubble's various deep fields, and records galaxies even fainter and farther that Hubble could see.

We see SMACS 0723 as it appeared "only" 4.6 billion years ago. But thanks to the cluster's huge mass, which acts as a gravitational lens to magnify and distort objects behind it, we can see galaxies that existed within a billion years of the Big Bang. As you might expect, the tiniest galaxies in the field lie farthest away. Intriguingly, they

JWST'S FAMILY TREE

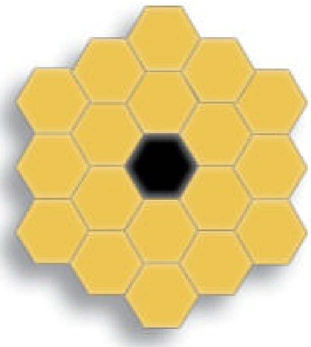
British scientist Sir Isaac Newton once famously said, "If I have seen further, it is by standing on the shoulders of giants." Similarly, the James Webb Space Telescope is building on the legacy of its forerunners. These earlier space-based infrared observatories helped pave its way.

Name	Year launched	Wavelength range (micrometers)	Aperture
Infrared Astronomical Satellite	1983	5–100	0.57 m
Infrared Space Observatory	1996	2.5–240	0.6 m
Spitzer Space Telescope	2003	3–180	0.85 m
Akari	2006	2–200	0.67 m
Herschel Space Observatory	2009	55–672	3.5 m
Wide-field Infrared Survey Explorer	2010	3–25	0.4 m
James Webb Space Telescope	2021	0.6–28.5	6.5 m

The face-on spiral NGC 7469 sports an active nucleus where gas and dust glow brilliantly as they fall into a supermassive black hole. This luminous infrared galaxy makes an ideal target for JWST, which reveals a bright ring of star formation as well as several other young star clusters. (The six bright spikes are an artifact of the reflecting telescope's design.) ESA/WEBB/NASA/CSA/L. ARMUS, A.S. EVANS

the Tarantula Nebula, see "Untangling the Tarantula Nebula" in the September 2021 issue.) The largest star-forming region in the local universe, the Tarantula forges new stars at a ferocious pace. Astronomers have cataloged some 820,000 stars to date, and the vast reservoirs of hydrogen and helium the nebula contains should be good for hundreds of thousands more. The brilliant star cluster at its center, dubbed R136, holds dozens of stars that weigh at least 100 solar masses.

JWST's initial observations reveal the Tarantula in unprecedented detail. Fierce radiation and stellar winds from the massive stars in R136 have cleared out a large bubble in the nebula's central region. Only the densest surrounding areas, likely harboring baby stars of their own, resist this onslaught. Because the nebula lies only 160,000 light-years from Earth — a mere stone's throw on a cosmic scale — the Tarantula gives astronomers a close-up view of conditions they'll encounter as they explore the cosmic noon in more depth.



THE SCIENCE, DISCOVERIES, AND BEAUTIFUL IMAGES HAVE ONLY JUST BEGUN.

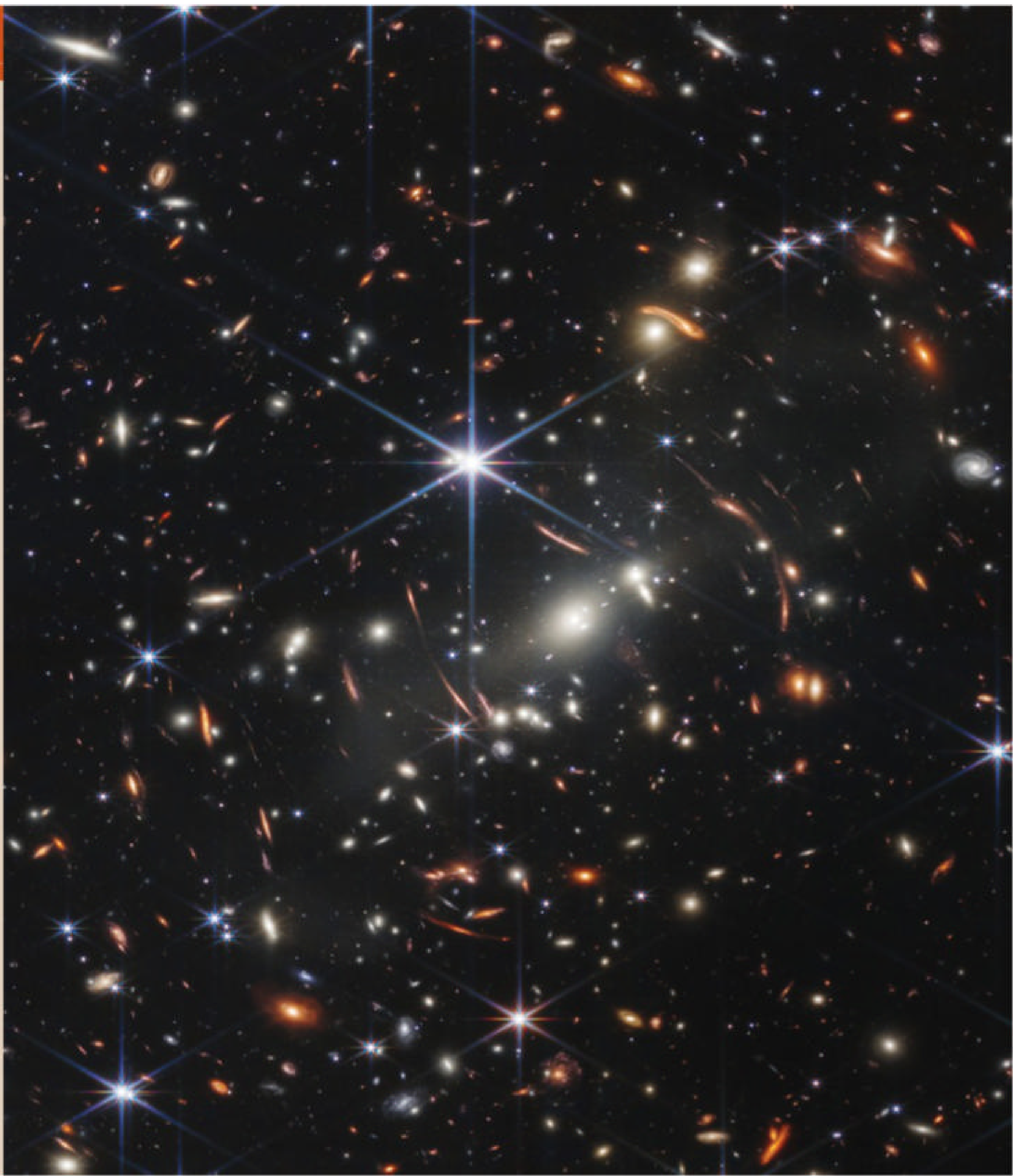
Contributing Editor **Richard Talcott***, who has reported on the Hubble Space Telescope for a third of a century, hopes JWST offers as many thrills. His latest book is* Space Junk *(Ziga Media, 2019).*

don't look anything like the more mature spiral and elliptical galaxies closer to Earth.

But perhaps the most significant discoveries so far are the two most remote galaxies ever seen. Using the massive galaxy cluster Abell 2744 in Sculptor as a gravitational lens, scientists uncovered two island universes that existed just 450 million and 350 million years after the Big Bang (which occurred 13.8 billion years ago). The galaxies appear exceptionally bright and likely would have started assembling only 100 million years after the Big Bang. Researchers don't yet know if the galaxies hold lots of dim stars or a few extraordinarily bright Population III stars — hypothetical massive stars consisted solely of hydrogen and helium that were the first stars to grace the cosmos.

JWST's ride on that Ariane 5 rocket went so smoothly that NASA now estimates the observatory has enough fuel to operate for at least 20 years. That means the science, discoveries, and beautiful images have only just begun.

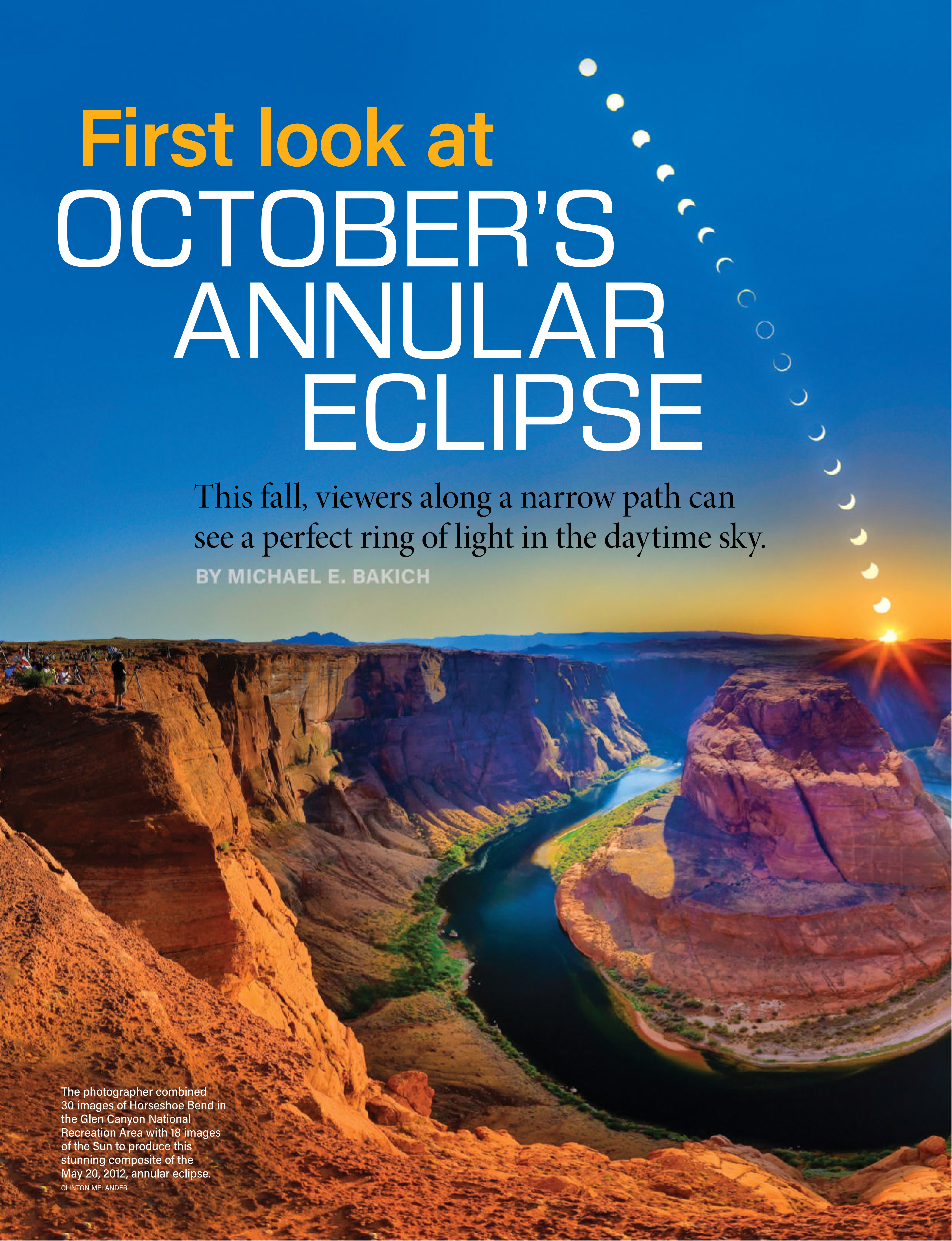
JWST's first deep-field photo captured the galaxy cluster SMACS 0723. The cluster members lie about 4.6 billion light-years from Earth and appear as white elliptical glows. Their mass creates a gravitational lens that magnifies and warps more remote galaxies, some of which existed less than a billion years after the Big Bang. NASA/ESA/CSA/STSCI



First look at OCTOBER'S ANNULAR ECLIPSE

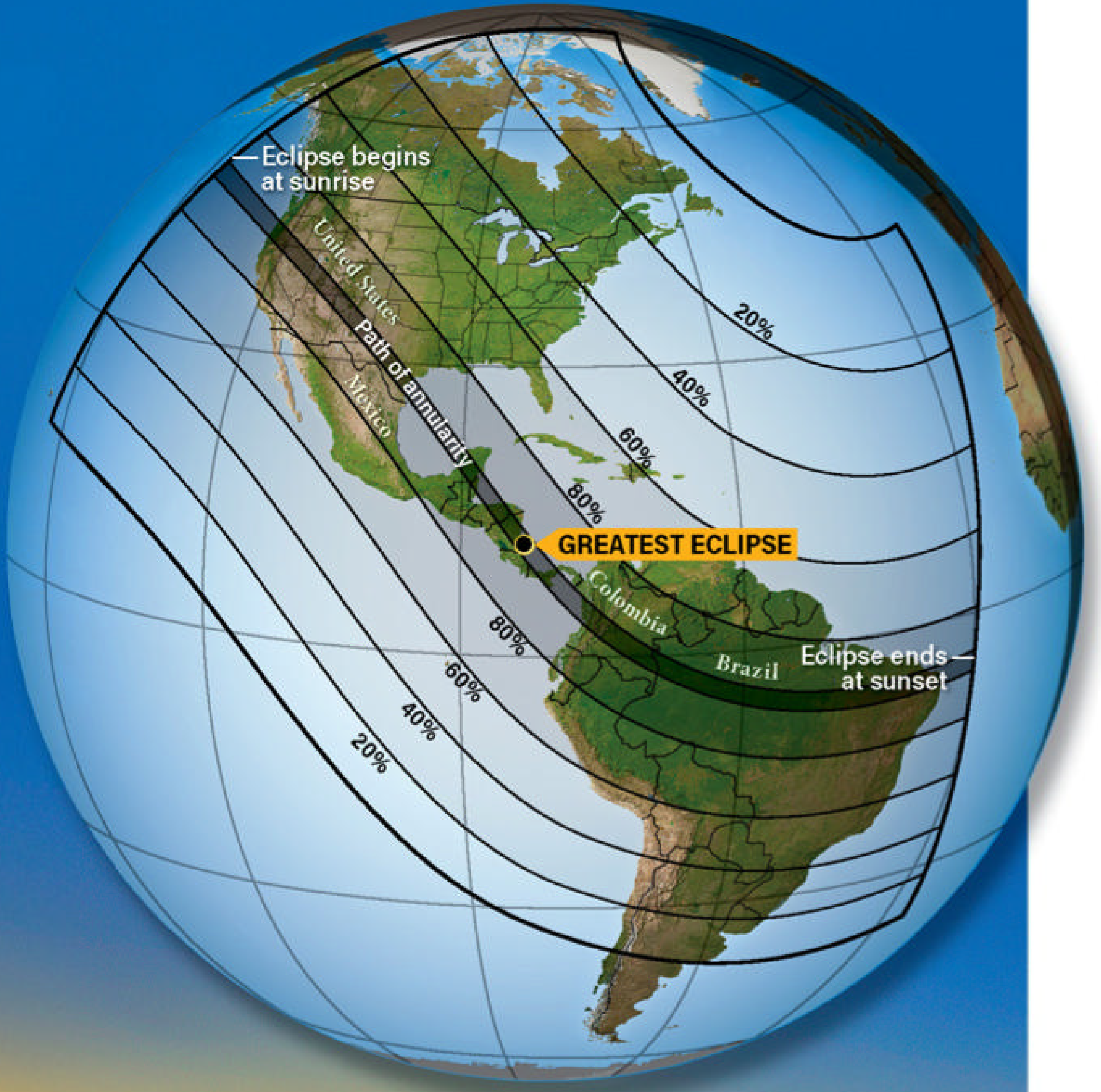
This fall, viewers along a narrow path can see a perfect ring of light in the daytime sky.

BY MICHAEL E. BAKICH



The photographer combined 30 images of Horseshoe Bend in the Glen Canyon National Recreation Area with 18 images of the Sun to produce this stunning composite of the May 20, 2012, annular eclipse.

CLINTON MELANDER



MARK YOUR CALENDARS!

On Oct. 14, an annular eclipse will cross the western U.S. from Oregon to Texas. Afterward, it will touch nine additional countries: Mexico, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Colombia, and Brazil.

In the U.S., approximately 6.6 million people lie in the path of annularity. Several hundred million more will see a partial eclipse, weather permitting. The number seeing the main part of the eclipse is low because only two big cities, Albuquerque and San Antonio, lie in the path.

Like during a total eclipse, an annular eclipse occurs when the Sun, the Moon, and Earth line up. In this case, however, either the Sun is too close or the Moon is too far from Earth for the Moon to completely cover the solar disk. So, only the antumbra, where the Moon appears completely within the disk of the Sun, touches the surface of Earth. Anyone within the path will see a ring of the Sun's surface surrounding the darkened Moon.

Please note that because part of our star's surface is always visible, you must use an approved solar filter (one that meets the ISO 12312–2 international safety standard) during the entire eclipse. This means over your eyes, your camera, and your binoculars or telescope — NO EXCEPTIONS!

The details

The eclipse starts when the Moon's penumbra (its lighter, outer shadow where a partial eclipse occurs) touches Earth at 11:04 A.M. EDT. That happens nearly 970 miles (1,560 kilometers) south of Ketchikan, Alaska, in the North Pacific Ocean.

The annular part of the eclipse begins at 12:10 P.M. EDT and ends at 3:49 P.M. EDT about 360 miles (580 km) off the coast of Brazil. Greatest eclipse occurs at 1:59 P.M. EDT in the Caribbean Sea, 60 miles (97 km) from the coast of Nicaragua. The last remnants of the Moon's shadow disappear into the night over northeastern Brazil at 4:55 P.M. EDT, about 220 miles (350 km)

ABOVE INSET: The path of annularity during the Oct. 14, 2023, annular eclipse touches 10 countries. This map also shows the percent of partial eclipse for locations off the path. *ASTRONOMY*: ROEN KELLY northeast of the Brazilian capital of Brasília. The shadow will have stayed on Earth's surface for 5 hours 51 minutes 29 seconds.

The magnitude of this eclipse is 0.952. This means that, as seen from Earth, the Moon's diameter is 95.2 percent as large as the Sun's diameter. At the eclipse's maximum, the Moon will cover 90.6 percent of our daytime star with annularity lasting 5 minutes 17 seconds. The eclipse will take place in the constellation Virgo, about 4° to the upper right of Spica (Alpha [α] Virginis), which will be invisible. Venus, some 46° west-northwest of the Sun, will be the only object in the sky bright enough to see. At magnitude –4.6, the planet should become visible several minutes before maximum eclipse. Because it's so far from the Sun, you can safely search for it through binoculars.

Oregon and California

The first part of the eclipse sees the antumbra traveling some 1,100 miles (1,770 km) over the northern Pacific Ocean. It touches land on the U.S. coast just west of Gardiner, Oregon, at 9:13 A.M. PDT. Annularity here will last 4 minutes 24 seconds.

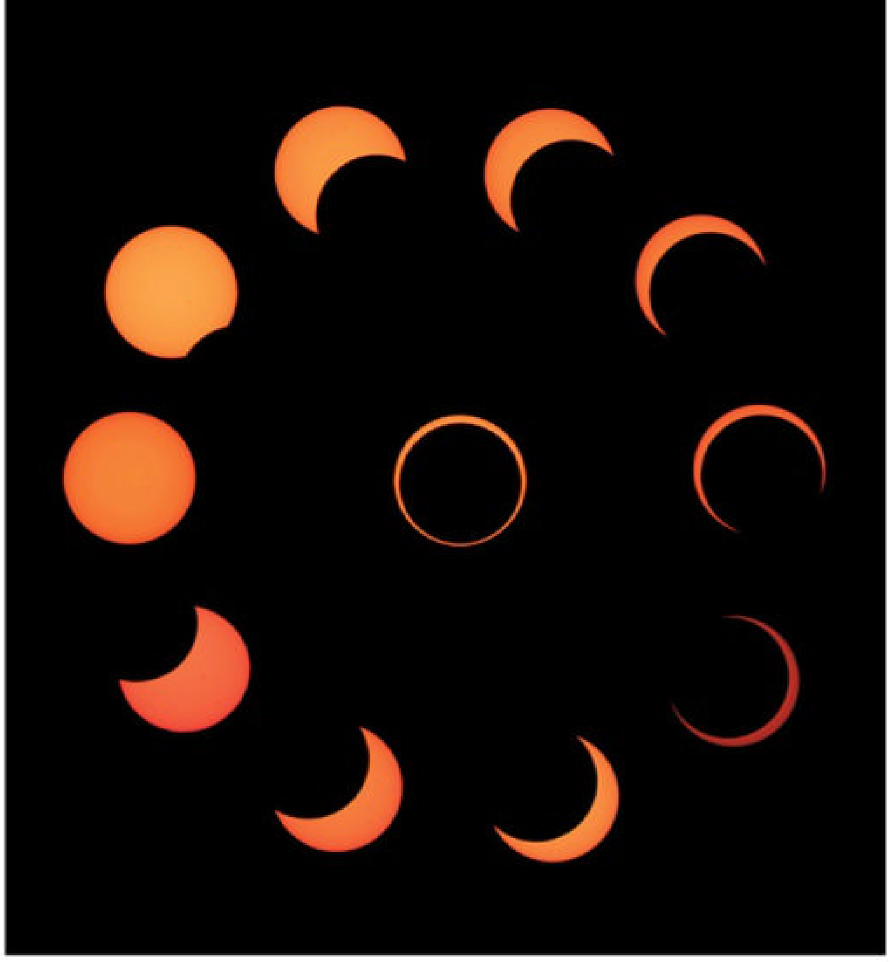
A great opportunity for photographers will occur just 125 miles (200 km) farther along the path as Crater Lake also enjoys 4 minutes 24 seconds of annularity. But be sure to check the availability of the roads around the lake — closings because of snow have happened by mid-October.

The antumbra continues to the southeast and next covers the extreme northeast corner of California. Tiny New Pine Creek, just east of Goose Lake, will experience 4 minutes 7 seconds of annularity.

Nevada, Idaho, and Utah

Annularity will begin in northwest Nevada at 9:19 A.M. PDT and end at the Utah border 10 minutes later. Note that in Utah, the time zone is Mountain Daylight Time. Maximum annularity in Nevada is between 4 minutes 33 seconds and 4 minutes 37 seconds, and the Sun's altitude climbs to 27° at the Utah border.

With a population around 20,000, the largest Nevada town touched by annularity is Elko. Access is easy because of Interstate 80, and there's a 70 percent chance of sunshine.



Photographers produced many different images of the May 2012 annular eclipse. For each of the 1⁄250-second shots in this composite, the imager used a Nikon D300 DSLR and 400mm Nikon lens at f/8 with a 2x extender, giving an effective focal length of 600mm. The shot was taken from Monument Valley, Utah. BEN COOPER/LAUNCHPHOTOGRAPHY.COM

In Idaho, only a tiny triangle with an area of 43 square miles (111 square km) sees annularity, but there are no towns in this region.

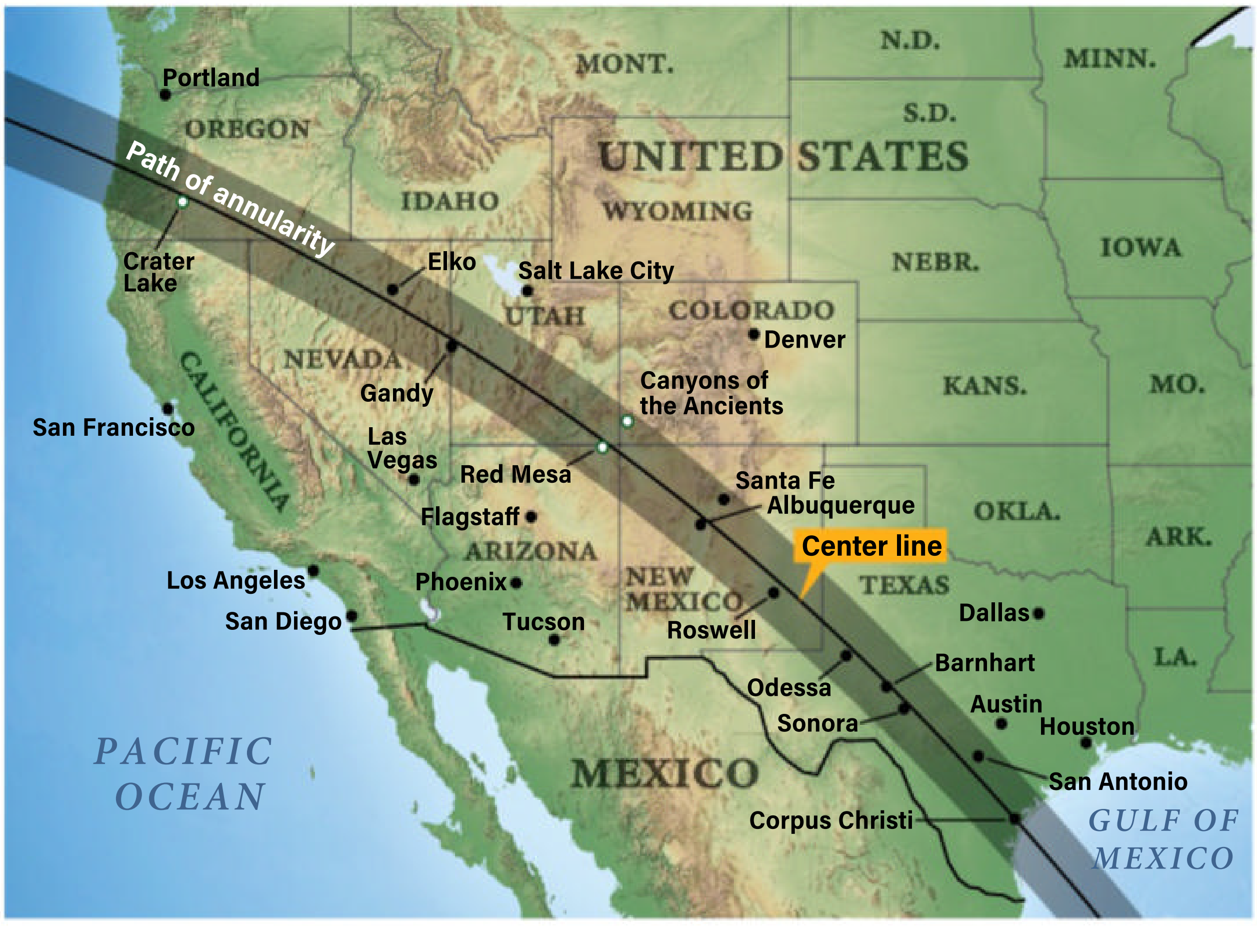
In Utah, the annular eclipse begins just west of Gandy at 10:24 A.M. MDT. The path passes over some gorgeous landscapes, but no large cities. However, both I-70 and I-15 allow easy drives to dozens of great locations.

Eclipse watchers into geography might choose to view from the Four Corners Monument, where the states of Utah, Colorado, New Mexico, and Arizona meet. That spot will feature 4 minutes 30 seconds of annularity with the Sun 33° high.

Arizona

The annular part of the eclipse reaches Arizona at 9:29 A.M. MDT, approximately 37 miles (60 km) east of Page, which lies outside the path. Eclipse chasers should drive south 66 miles (106 km) along State Route 98 and then another 87 miles (140 km) east on U.S. Highway 160 to Red Mesa. There, annularity lasts 4 minutes 41 seconds.

Flagstaff doesn't get annularity, but will be a base for eclipse chasers. Anyone staying there can drive 68 miles (109 km)


Portland
OREGON
MONT.
N.D.
MINN.
S.D.
UNITED STATES
Path of annularity
IDAHO
WYOMING
IOWA
Crater Lake
Elko
Salt Lake City
NEBR.
UTAH
COLORADO
Denver
NEVADA
Gandy
Canyons of the Ancients
KANS.
MO.
San Francisco
CALIFORNIA
Las Vegas
Red Mesa
Santa Fe
Albuquerque
OKLA.
Flagstaff
ARIZONA
Center line
ARK.
Los Angeles
Phoenix
NEW MEXICO
TEXAS
San Diego
Tucson
Roswell
Dallas
LA.
Barnhart
Odessa
Austin
Sonora
Houston
PACIFIC OCEAN
MEXICO
San Antonio
Corpus Christi
GULF OF MEXICO

Most eclipse chasers will head to New Mexico and Texas, the area shown on this map. Annularity will last longer here than along the path to the northwest, and the weather prospects are also the best there. *ASTRONOMY*: ROEN KELLY north on U.S. Highway 89, and then take U.S. Highway 160 to the path.

Colorado

Three minutes after the antumbra touches Arizona, it enters Colorado about 12 miles (19 km) northwest of Dove Creek. The state's best viewing spot is the far southwestern corner, where U.S. Highway 160 enters Arizona. There, annularity lasts 4 minutes 30 seconds.

Photographers might want to head to Canyons of the Ancients National Monument. The duration of annularity drops to 3 minutes 19 seconds, but the density of archaeological remains is the highest in the U.S.

New Mexico

The first large city covered by the antumbra during this eclipse will be Albuquerque. Its more than a half-million residents will enjoy 4 minutes 42 seconds of annularity. Santa Fe, closer to the northern limit, gets two minutes less.

Those with a sense of irony might choose to view the annular eclipse from the village of Corona (4 minutes 36 seconds of annularity). Or perhaps you have a sense of humor and would enjoy the festivities in Roswell (4 minutes 30 seconds), where, in 1947, a "flying disc" supposedly crashed north of the city.

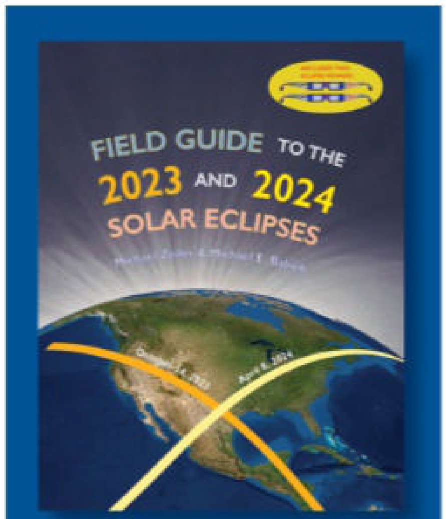
Texas

Texas first gets annularity at 11:41 P.M. CDT, 25 miles (40 km) west of Tatum, New Mexico. Note that Texas observes Central Time. One astronomy destination in Texas is Odessa, home of the Odessa Meteor Crater. Anyone there will experience 4 minutes 20 seconds of annularity. For 28 more seconds of annularity, drive 23 miles (37 km) northeast to the center line.

As the antumbra moves toward the Gulf of Mexico, it covers a lot of populated territory. No less than three interstate highways — I-10, I-35, and I-37 — run hundreds of miles through this area. The towns of Midkiff, Stiles, Barnhart, and Sonora lie on or near the center line.

And then the eclipse comes to San Antonio. The metro area's 2.6 million residents will see between 3 minutes 24 seconds and 4 minutes 44 seconds of annularity. The northeastern parts of the metro area will have the least time and those in the southwest suburbs will enjoy the most. And talk about photographic opportunities!

The Alamo Mission — the No. 1 tourist attraction in Texas — certainly will be high on the list. Annularity there will last 4 minutes 5 seconds. To capture both the eclipsed Sun and the Alamo, seek out a spot to the north-northwest. Right next to the Alamo is another photogenic site, the Hemisfair park, with its 750-foot-tall (229 meters) Tower of the Americas.



You'll find all the details about the 2023 annular eclipse in this book by the author and noted eclipse mapmaker Michael Zeiler. It's available now at www.MyScienceShop.com. MICHAEL E. BAKICH

Finally, 130 miles (209 km) southeast of San Antonio, the annular eclipse comes to the coast at Corpus Christi. Viewers just north of downtown will enjoy annularity lasting up to 4 minutes 53 seconds. The actual last point of contact for the antumbra in the U.S. happens at 12:01 P.M. CDT on Padre Island on the Gulf Coast.

Mexico

After a quick trip across the Gulf of Mexico, the antumbra reaches the state of Yucatán, Mexico, at 12:21 P.M. CDT, where photographers can capture the eclipsed Sun above several ancient archaeological sites. Uxmal, one of the great cities of the Mayans, lies about 37 miles (60 km) south of Merida. There, annularity will last 3 minutes 50 seconds.

Another Mayan archaeological site with even more annularity is Edzná, which lies southeast of Campeche City. There, annularity will last 4 minutes 32 seconds. After these highlights, only a few small towns lie along the center line. One is Nicolás Bravo,where annularity will last 5 minutes 1 second.

Central America

At 11:29 P.M. Belize Time, the Moon's antumbra will cross the Hondo River north of Orange Walk Town. From the center line there, the roughly 15,000 residents will enjoy 5 minutes 1 second of annularity. The capital, Belmopan, will have 2 minutes 45 seconds, and Belize City will have 5 minutes of annularity.

Then the antumbra arrives in Honduras. The country's third-largest city, La Ceiba, just west of the center line, will enjoy 5 minutes of annularity.

Nicaragua is next. The best place to view the eclipse is Bluefields, which lies on the eastern coast. The center line passes just north of the city, which will see 5 minutes 5 seconds of annularity.

Costa Rica doesn't get much annularity, but Panama's northwestern region will experience an annular eclipse lasting between two and four minutes. The greatest duration of annularity over land — 5 minutes 7 seconds — is in the northern part of Santa Fé National Park.

South America

On this continent, the Moon's antumbra travels over only two countries. In Colombia, the largest city covered is Cali, where annularity will last from 2 minutes 54 seconds to 3 minutes 43 seconds.

As the eclipse moves into Brazil, annularity begins along the center line at 2:55 P.M. Amazon Time, some 30 miles (48 km) due north of the village of La Pedrera. The largest city covered is Natal, which will experience between 3 minutes 10 seconds and 3 minutes 40 seconds of annularity. Then, at 4:48 P.M. Brasília Time, the antumbra begins its final 400-mile (644 km) journey over open water, ending at sunset.

The big one is coming

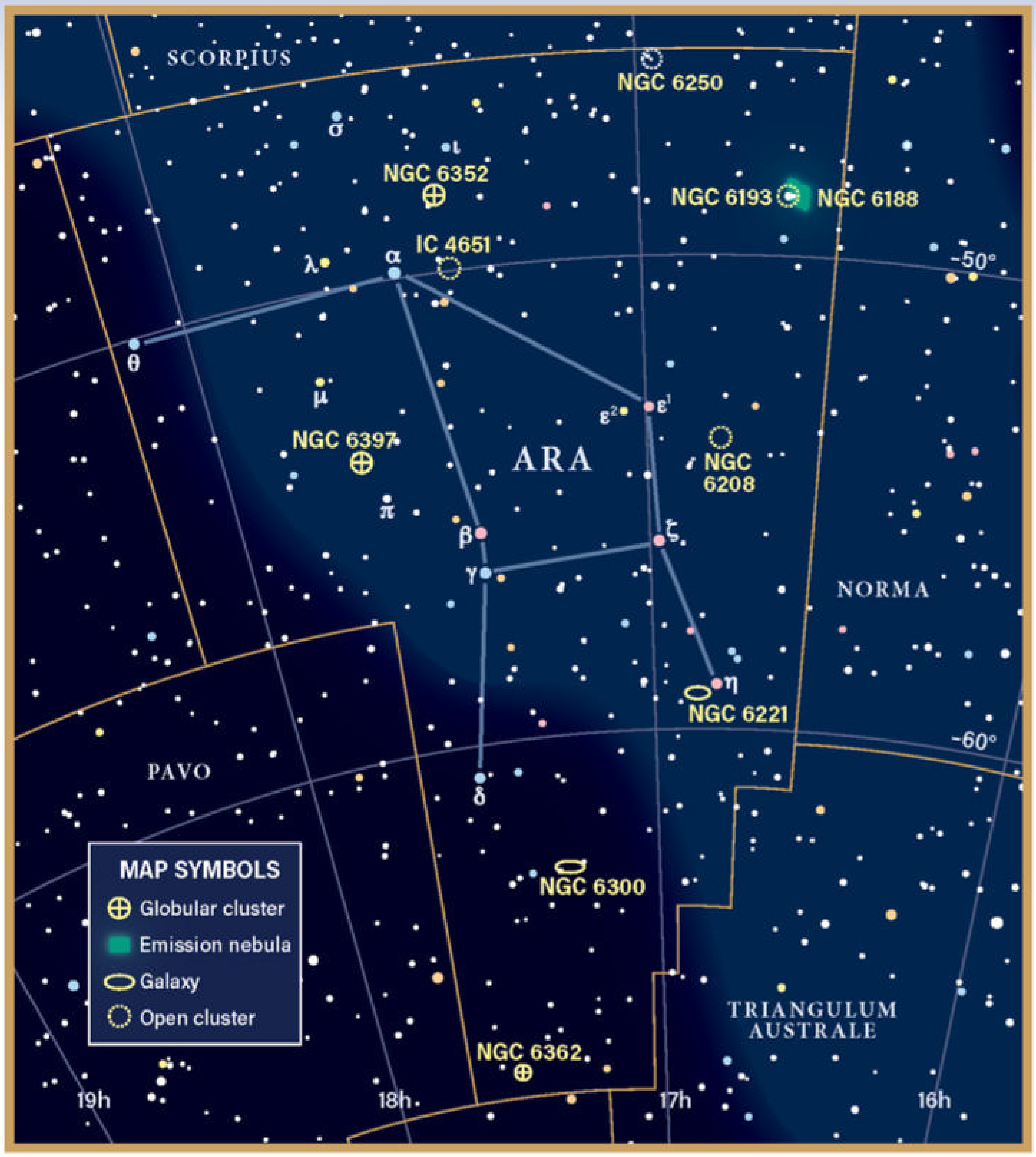
As cool as this annular eclipse will be, it's just a warm-up for a much more spectacular event. Less than six months from Oct. 14, a total solar eclipse will cross the U.S. on April 8, 2024. So, see this one if you can, but do not miss totality!

Michael E. Bakich *is a contributing editor of* Astronomy *who last saw annularity in 2012.*

OBSERVE THE DEEP SKY IN ARA

This small, often-overlooked constellation contains several observing treasures worth your while.

BY MICHAEL E. BAKICH


SCORPIUS
NGC 6250
σ
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NGC 6352
NGC 6193
NGC 6188
IC 4651
λ
α
–50°
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ε¹
NGC 6397
ARA
NGC 6208
π
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ζ
γ
NORMA
η
NGC 6221
–60°
PAVO
δ
MAP SYMBOLS
⊕ Globular cluster
🟩 Emission nebula
⬭ Galaxy
◌ Open cluster
NGC 6300
TRIANGULUM AUSTRALE
NGC 6362
19h
18h
17h
16h

There's plenty to see in the constellation Ara the Altar. *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

THE CONSTELLATION ARA (pronounced AIR-uh) the Altar was one of the "original" constellations of the Greeks. It appeared in *Phaenomena*, a 3rd-century-B.C. work by the Greek poet Aratus. He based it on a work written a century earlier by Eudoxus of Cnidus. The constellation's position is easy to locate directly beneath the tail of Scorpius. Making an altar out of the stars is more difficult.

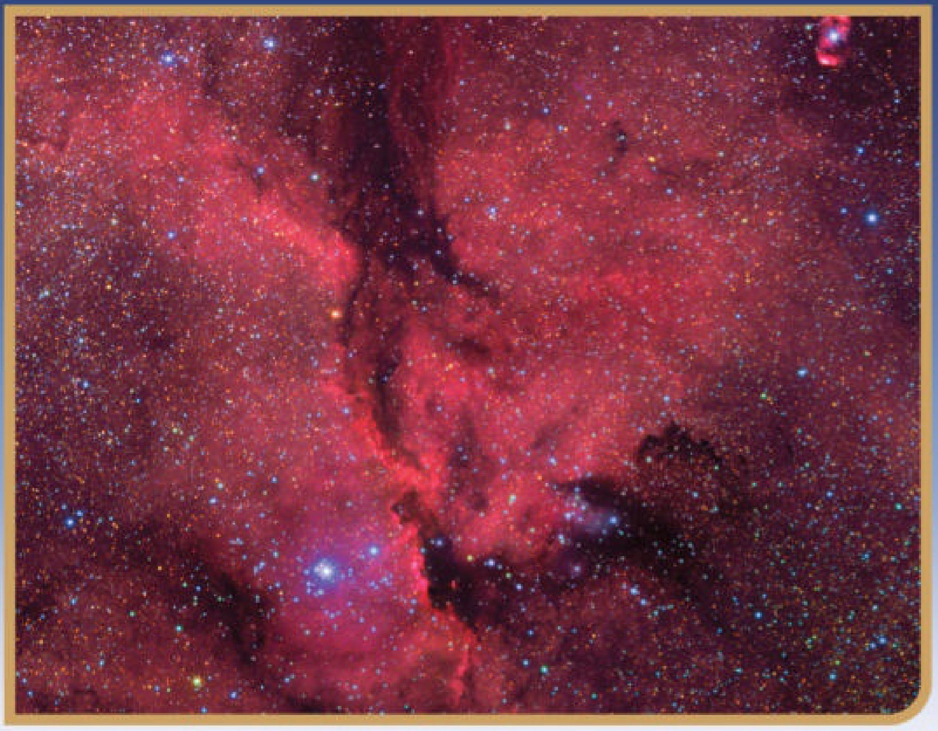
Ara is visible May through July in the Northern Hemisphere, the time Scorpius hangs directly in the south. Its center lies at right ascension 17h18m and declination –56°30'.

Ranking 63rd in size out of the 88 constellations, Ara covers 237.06 square degrees (0.575 percent) of the sky. And while its size is nearer to the bottom than the top of that category, it fares somewhat better (34th) in terms of overall brightness.

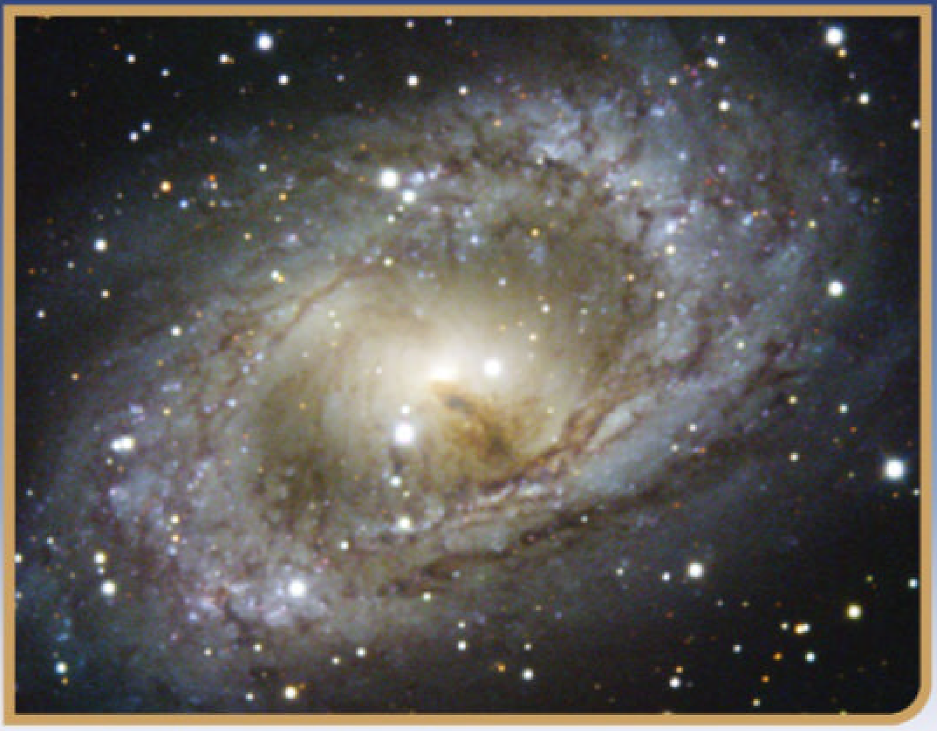
The best date to see Ara is June 10, when it stands opposite the Sun in the sky and reaches its highest point at local midnight. Your location will make a difference, however: The constellation is completely visible from latitudes south of 22° north and completely invisible from latitudes north of 45° north.

Although this star pattern isn't huge or bright, it offers some worthy treats for observers. Among them are open and globular clusters, an emission nebula, and a couple nice galaxies. So, consider heading south if necessary to reach the Altar and all the underobserved deep-sky objects it holds. Good luck!

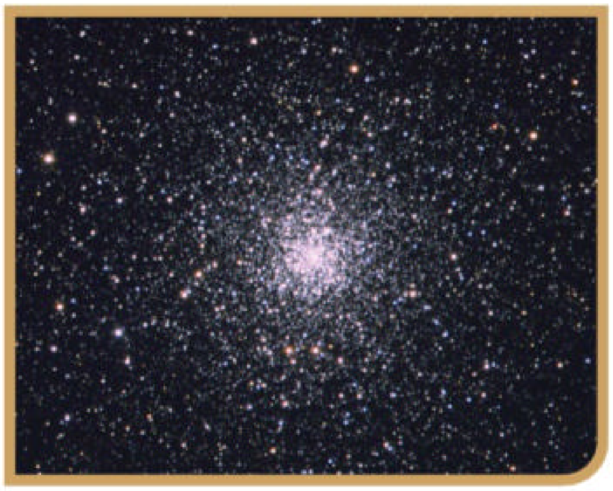
Michael E. Bakich *is a contributing editor of* Astronomy *who enjoys slowly moving his telescope through a single constellation.*



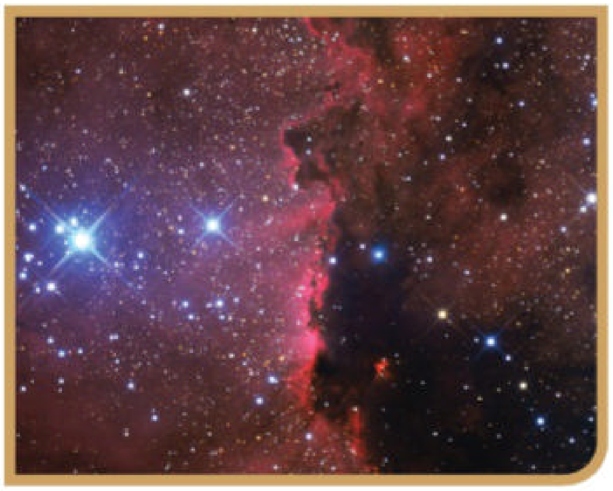
NGC 6188 is a combination emission/reflection nebula. Even a 4-inch scope will reveal a faint haze measuring 20' by 12' that interacts with open cluster NGC 6193. Larger scopes will reveal a dark region separating the eastern and western halves. GERALD RHEMANN



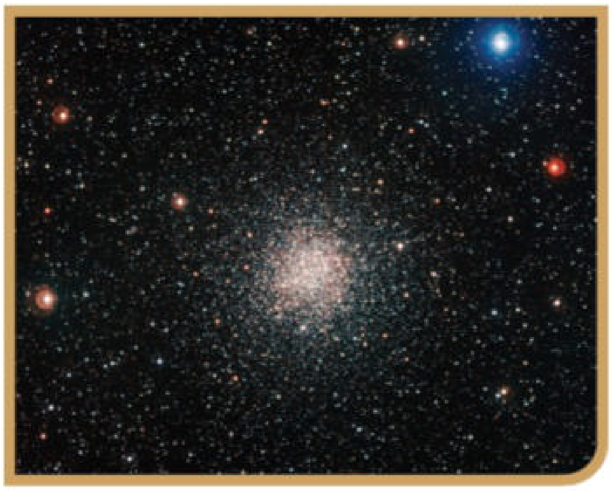
Barred spiral galaxy NGC 6300 glows at magnitude 10.1 and measures 5.2' by 3.3'. Of interest are the four 13th-magnitude foreground stars: two over the core, and one each on the northern and southern ends. ESO/C. SNODGRASS



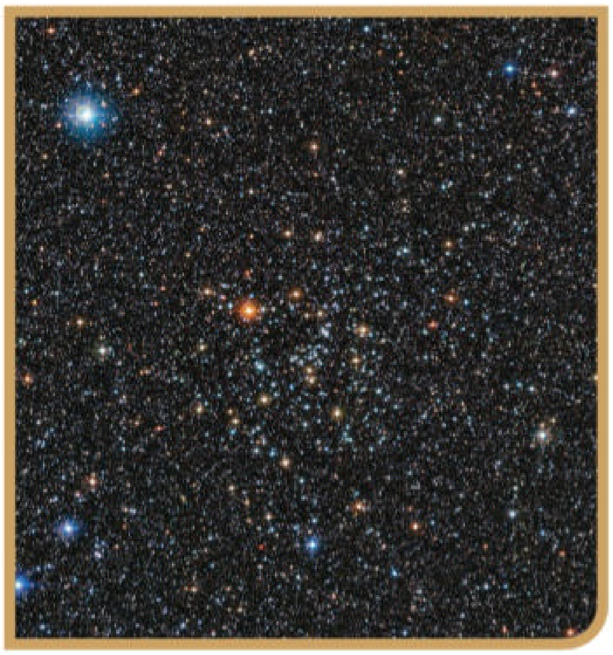
As the sky's fourth-brightest globular cluster (tied for that honor with NGC 6752 in Pavo), magnitude 5.3 NGC 6397 certainly would have earned a Messier designation if it were in the northern sky. Keen observers see it easily with their naked eyes as a fuzzy star. An 8-inch telescope at 200x reveals 50 stars. MICHAEL SIDONIO



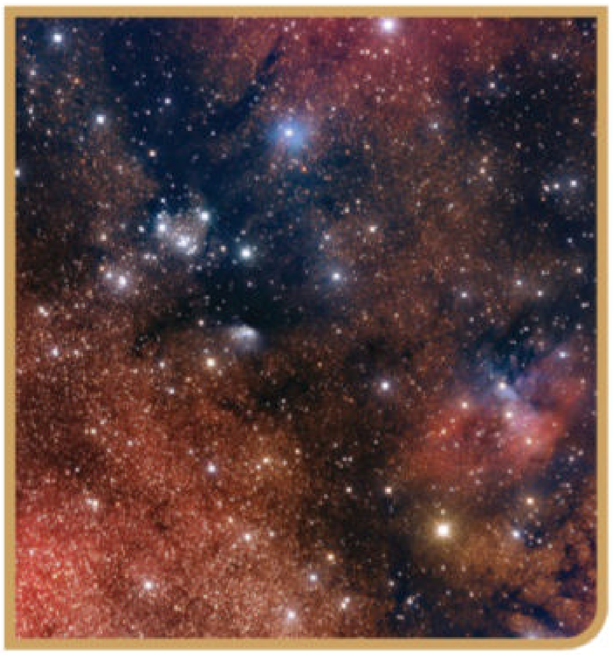
At magnitude 5.2, open cluster NGC 6193 is bright enough for sharp-eyed observers to spot beneath a dark sky without optical aid. This quarter-degree-wide stellar wedge, also known as Caldwell 82, contains two relatively bright stars and about a dozen faint ones. GERALD RHEMANN



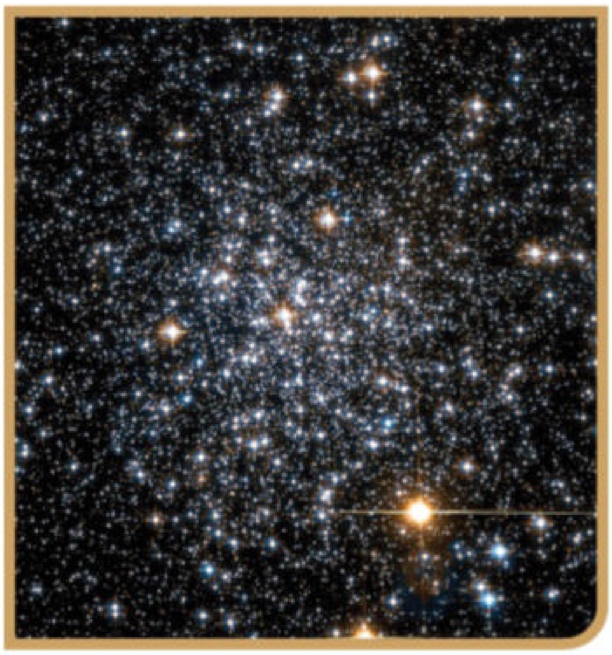
Globular cluster NGC 6362 glows at magnitude 7.5. Because it lies in a rich field of faint stars, it's quite easy to spot. The cluster has a diameter of 10.7' and responds well to high magnifications. Use 250x or more through an 11-inch scope. ESO



Magnitude 6.9 IC 4651 is a gorgeous open cluster with a rough arrowhead shape pointing west-northwest. Even a 3-inch telescope will resolve 50 points across its 12' diameter that stand out nicely from the surrounding star field. ESO



NGC 6250 is an open cluster right at the Ara-Scorpius border. Small scopes show about a dozen stars in this magnitude 5.9 object, but an 11-inch instrument will let you see dozens more. The five brightest form a rough, wide M. ADAM BLOCK (DATA PROVIDED BY JOSE JOAQUIN PEREZ)



Peer at globular cluster NGC 6352 through binoculars and you'll see that it lies in a really bright star field. The cluster stands out well because it glows at magnitude 8.1. A telescope shows a hazy object with a slightly brighter core. NASA

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING

The Beehive Cluster (right) in Cancer receives two visitors this month: First Mars (shown here at left) as the month opens, then Venus less than two weeks later. ALAN DYER

Buzzing through the Beehive

Venus reaches its best for the year as an evening object this month. Its brilliance captures attention long after sunset. Meanwhile, Mars continues to fade but enjoys a beautiful meeting with the Beehive Cluster, a view not to be missed. Saturn and Jupiter appear after midnight and offer some fine views, while the predawn sky hosts Mercury, best seen in the first half of June.

Soon after sunset you'll find **Venus** high in the evening sky, reaching its greatest eastern elongation June 4. At 45° from the Sun, the planet remains a spectacular evening star for more than three hours after sunset. It stays highly visible all month, unmissable as it starts out at magnitude –4.4 and brightens to magnitude –4.7 by the end of June.

On June 1, Venus is in Gemini, 30° above the western horizon 30 minutes after sunset. The planet lines up with Castor and Pollux, the constellation's twin 1st-magnitude stars. It crosses into Cancer June 3 and stands 10° from Mars, which is located nicely next to the Beehive Cluster (M44; more on that shortly).

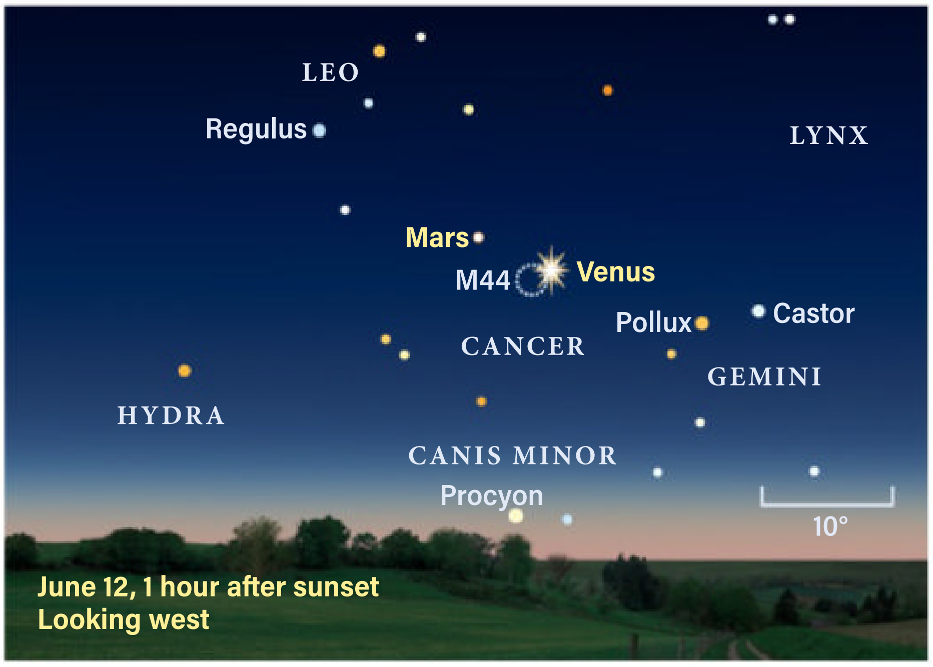
A telescopic view reveals Venus is 50 percent lit, although the timing of this so-called dichotomy is affected by a variety of circumstances. Called Schröter's effect, Venus can appear exactly half lit a few days before eastern elongation. Astronomers believe this effect is due to a combination of light scattering at twilight combined with the shading near the terminator of Venus. Watch the planet for the few days before and after greatest elongation and make your best judgment.

Entering the second week of June, Venus approaches the Beehive Cluster, arriving within 1.1° of these stars on June 12 and standing 0.8° north of M44 on the 13th.

Whenever a crescent Moon joins Venus, the view in evening twilight is stunning. You'll see this pairing on June 21, when the two are 3° apart. Mars, in Leo, stands 4.5° from Venus, while M44 lies 7° west of Venus.

Venus continues to chase the Red Planet, narrowing the gap between them to less than 4° by June 30 but never quite catching up, so there's no real conjunction. Regulus, Leo's brightest star, is less than 6° from Mars on this last day of the month. The telescopic view of Venus has changed radically, now showing a 32-percent-lit crescent spanning 34". Venus sets shortly

Passing Praesepe



Just before midmonth, Venus mingles with the Beehive Cluster (M44, also called Praesepe) in Cancer, while Mars stands nearby. Earlier in June, Mars passes M44. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

MARS passes through the stars of the Beehive Cluster June 1 and 2. **VENUS** follows suit June 12 and 13.

before 11 P.M. local daylight time on June 30.

Mars dims 0.1 magnitude to 1.7 during June as it precedes Venus across Cancer and moves into Leo just after midmonth. Don't miss the Red Planet nestled among the stars of M44 on June 1 and 2. The binocular view is beautiful; the telescopic view is stunning. Mars is a brilliant magnitude 1.6 ruby embedded in a sea of fainter diamonds. Catch it early, soon after 9 P.M. local time. By the end of June, Mars is setting an hour before midnight.

Mars displays a tiny 5"-wide disk in telescopes. It continues its slow progression toward a November solar conjunction and remains in the evening sky for a few more months.

Saturn rises at 1:30 A.M. local time on June 1 and is well above the horizon in the east by midnight on June 30. It's two months from opposition and a fine target for any telescope. Located in the middle of Aquarius, Saturn rises to about 40° elevation by sunrise from mid-latitudes in the U.S. It's the brightest object between the Square of Pegasus and the 1st-magnitude star Fomalhaut, which rises a little more than 90 minutes after Saturn.

The ringed planet shines at magnitude 0.8 early in the month. Through a telescope, its yellowish disk is 17" across. The rings' tilt reaches a minimum for the year this month at 7.3°. Their long axis subtends 40", while the narrow axis is just shy of 5".

Saturn's brightest moon, Titan, shines at magnitude 8.6. It is due north of the planet June 5 and 21, and due south June 13 and 29. Other, fainter moons are closer to the planet, shining from 9th to 11th magnitude.

Iapetus reaches western elongation June 24, when it shines brighter than average.

— *Continued on page 34*

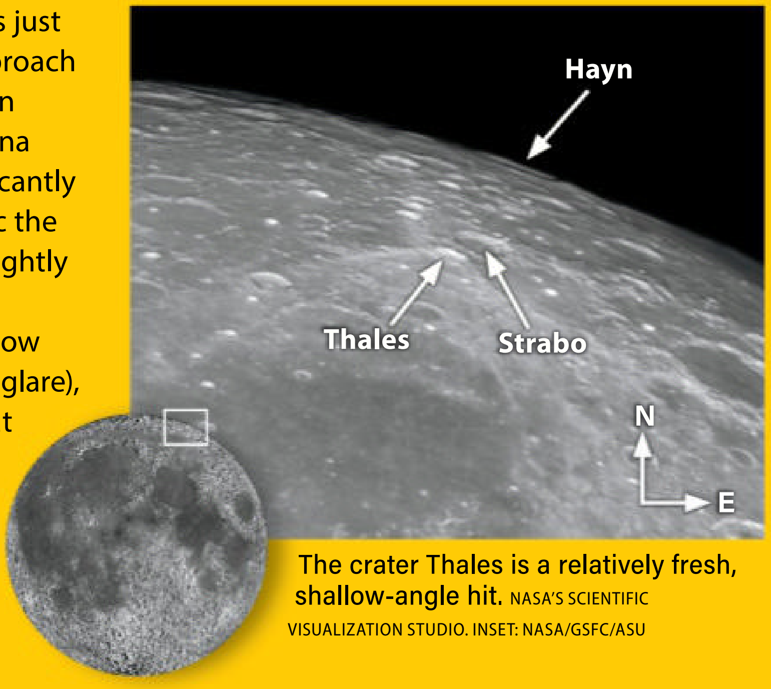
RISING MOON | Almost extremes

OUR MEDIA does not celebrate second-place finishes very well, but this month's Full Moon on the 3rd has plenty of them. The Moon is just over two days from perigee, its closest approach to Earth, puffing out to a mere 1.2' less than the 33.7' of August's coming maximum. Luna remains yellow tonight thanks to its significantly negative declination, tracing the lowest arc the Full Moon can take — *this* year. It will be slightly outdone in 2024.

Take in the fantastic rays from Tycho at low power (use a blue filter to cut down on the glare), then boost the magnification and check out the far northeast limb. Where one ray passes east of the long Mare Frigoris, there's a countering V shape of rays spreading back. The point of the V is the crater Thales, named for the Greek mathematician. Not only is this a classic "fresh" impact crater (still a few hundred million years old), it is a shallow-angle hit that makes butterfly rays like Proclus on the west side of Mare Crisium. The shallowness of the angle isn't as extreme as Messier farther south, though.

Pass through Strabo and onto the limb to pick out Hayn, just about in profile. The low and flat Mare Humboltianum reveals its depth on the 4th as it lies in shadow, giving the limb quite a divot. Speaking of shadows, the ones close to the north pole are putting on a striking 3D show (as showcased in the July 2021 issue). The view practically repeats July 2nd.

Thales and Strabo



The crater Thales is a relatively fresh, shallow-angle hit. NASA'S SCIENTIFIC VISUALIZATION STUDIO. INSET: NASA/GSFC/ASU

METEOR WATCH | Midnight glow

High-flying clouds

Noctilucent clouds shine in the late-summer sky above the Vuosaari district in Helsinki. TIMO NEWTON-SYMS

THERE ARE NO major meteors showers in June, but look out for those beautiful sporadic summer meteors that can coast across the Milky Way (or anywhere in the sky) at random moments.

Midsummer is also the time of year when more northerly locations get to experience noctilucent clouds. North of 55° latitude in Canada and northern Europe are good places to view these iridescent clouds, which sit some 10 times higher than cirrus and glow long after lower-level clouds appear dark. Noctilucent clouds are produced when ice crystals form on tiny dust particles; sunlight can illuminate them even at local midnight. In recent years, time-lapse photography has produced beautiful evidence of the ebb and flow of these elusive visitors of the night.

STAR DOME

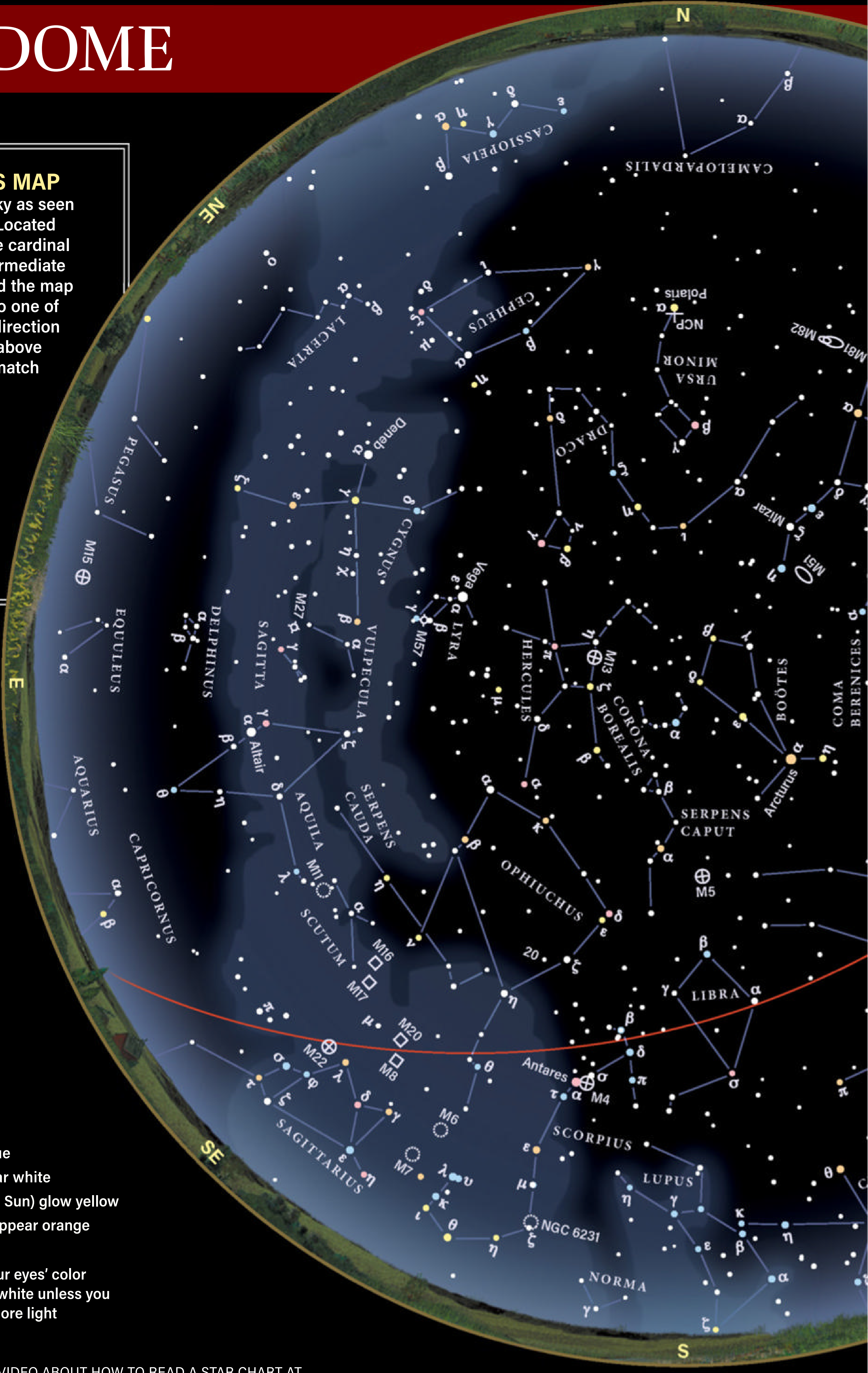
HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight June 1
11 P.M. June 15
10 P.M. June 30

Planets are shown at midmonth


N
NE
E
SE
S
CASSIOPEIA
CAMELOPARDALIS
CEPHEUS
LACERTA
Polaris
NCP
URSA MINOR
M81
M82
DRACO
Deneb
PEGASUS
CYGNUS
Vega
LYRA
M57
M15
EQUULEUS
DELPHINUS
SAGITTA
M27
VULPECULA
HERCULES
M13
CORONA BOREALIS
BOÖTES
COMA BERENICES
Mizar
M51
Arcturus
SERPENS CAPUT
M5
Altair
AQUILA
SERPENS CAUDA
AQUARIUS
CAPRICORNUS
OPHIUCHUS
M11
SCUTUM
M16
M17
LIBRA
M20
M22
M8
Antares
M4
SCORPIUS
M6
M7
SAGITTARIUS
LUPUS
NGC 6231
NORMA

MAP SYMBOLS

- ◌ Open cluster
- ⊕ Globular cluster
- □ Diffuse nebula
- ⌖ Planetary nebula
- ⬭ Galaxy

STAR MAGNITUDES

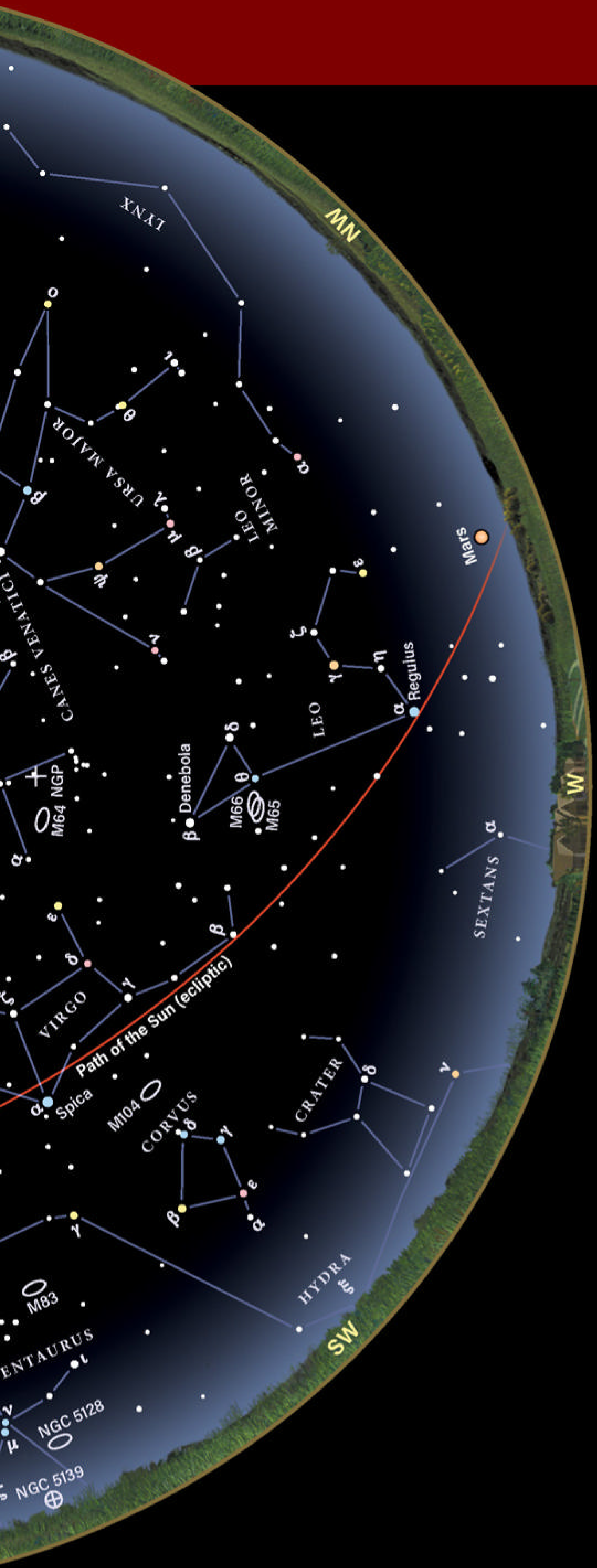
● Sirius
● 0.0
● 1.0
• 2.0
• 3.0
• 4.0
· 5.0

STAR COLORS

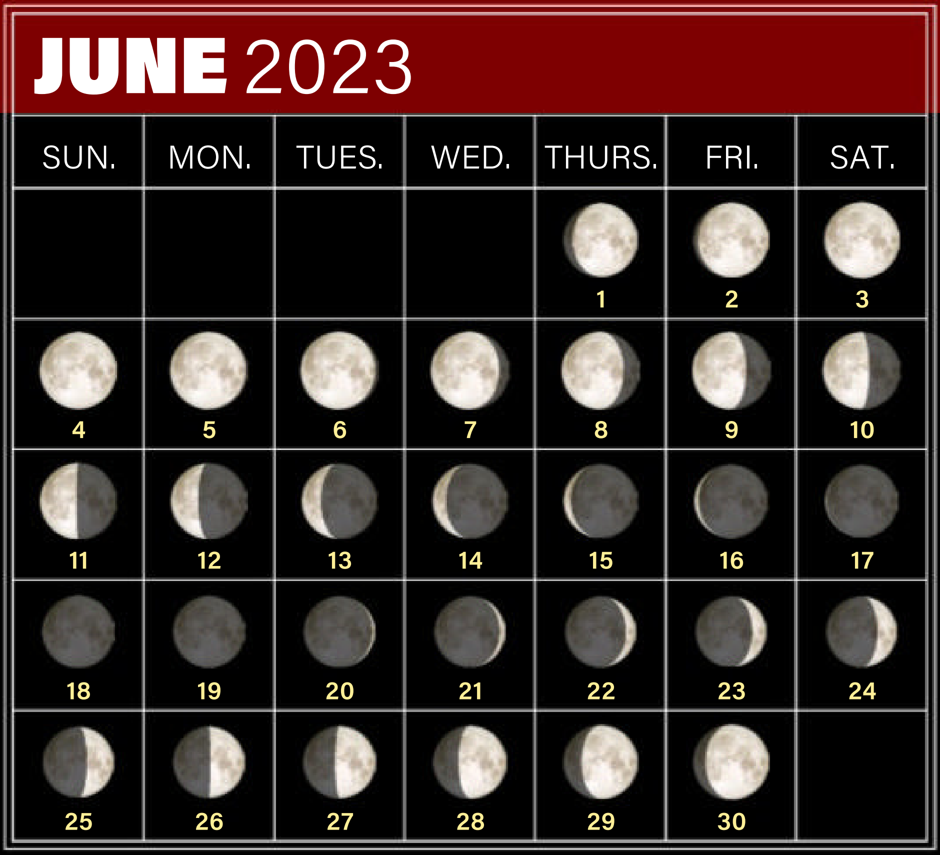
A star's color depends on its surface temperature.

- 🟦 The hottest stars shine blue
- ⬜ Slightly cooler stars appear white
- 🟨 Intermediate stars (like the Sun) glow yellow
- 🟧 Lower-temperature stars appear orange
- 🟥 The coolest stars glow red
- ⬜ Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**


LYNX
NW
URSA MAJOR
LEO MINOR
CANES VENATICI
Mars
Regulus
LEO
Denebola
M66
M65
M64
NGP
W
SEXTANS
VIRGO
Path of the Sun (ecliptic)
Spica
M104
CORVUS
CRATER
HYDRA
SW
M83
ENTAURUS
NGC 5128
NGC 5139

JUNE 2023



SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

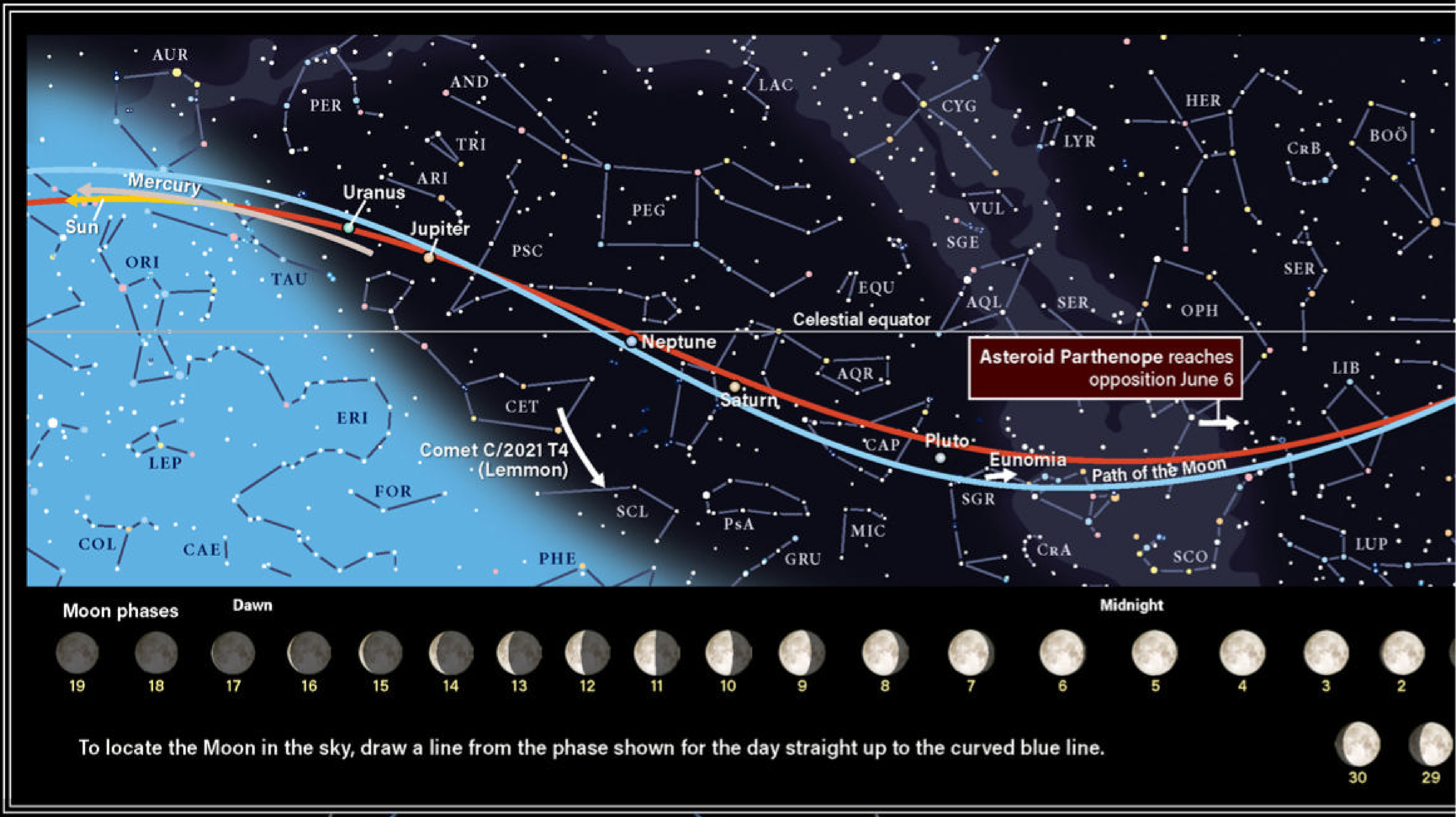
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

3	Full Moon occurs at 11:42 P.M. EDT
4	Mercury passes 3° south of Uranus, 1 A.M. EDT
	Venus is at greatest eastern elongation (45°), 7 A.M. EDT
6	Asteroid Parthenope is at opposition, 5 A.M. EDT
	The Moon is at perigee (226,714 miles from Earth), 7:06 P.M. EDT
9	The Moon passes 3° south of Saturn, 4 P.M. EDT
10	Last Quarter Moon occurs at 3:31 P.M. EDT
11	The Moon passes 2° south of Neptune, 4 A.M. EDT
14	The Moon passes 1.5° north of Jupiter, 3 A.M. EDT
15	The Moon passes 2° north of Uranus, 6 A.M. EDT
16	The Moon passes 4° north of Mercury, 5 P.M. EDT
17	Mercury passes 4° north of Aldebaran, 10 A.M. EDT
18	New Moon occurs at 12:37 A.M. EDT
	Saturn is stationary, 11 A.M. EDT
20	Asteroid Juno is in conjunction with the Sun, 4 A.M. EDT
21	Summer solstice occurs at 10:58 A.M. EDT
	The Moon passes 4° north of Venus, 9 P.M. EDT
22	The Moon passes 4° north of Mars, 6 A.M. EDT
	The Moon is at apogee (251,895 miles from Earth), 2:30 P.M. EDT
26	First Quarter Moon occurs at 3:50 A.M. EDT

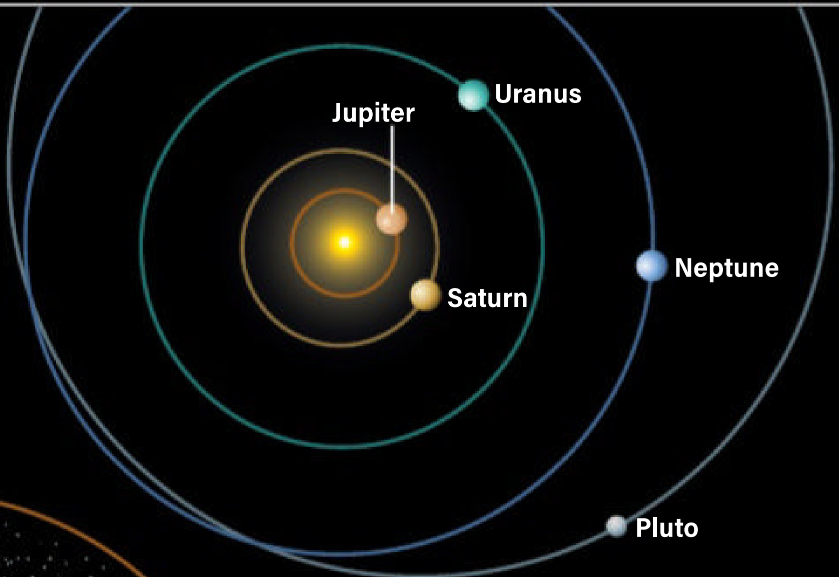
PATHS OF THE PLANETS

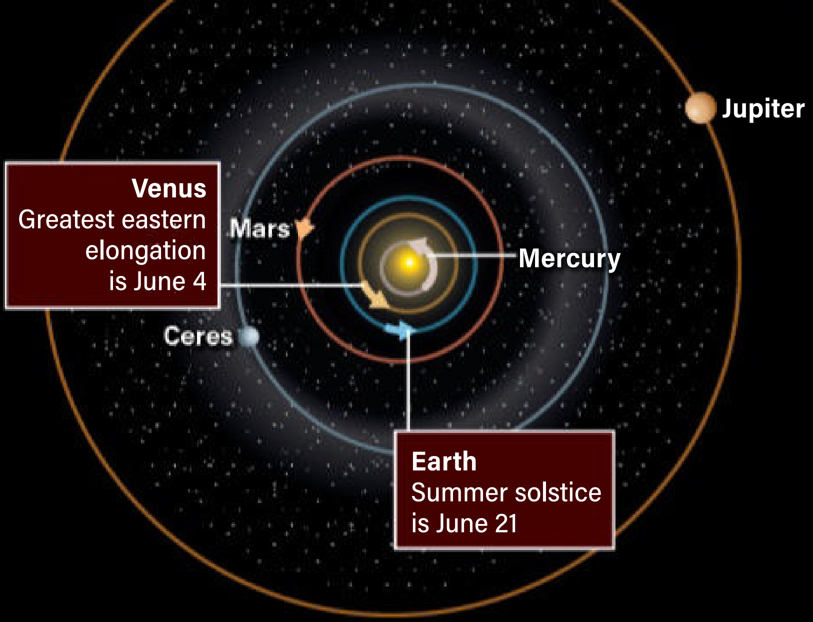

AUR
AND
LAC
CYG
HER
PER
TRI
LYR
CrB
BOÖ
ARI
Mercury
Uranus
Sun
Jupiter
PEG
VUL
SGE
PSC
ORI
TAU
EQU
SER
AQL
SER
OPH
Celestial equator
Neptune
Asteroid Parthenope reaches opposition June 6
LIB
AQR
Saturn
CET
ERI
LEP
CAP
Pluto
Eunomia
Path of the Moon
Comet C/2021 T4 (Lemmon)
FOR
SGR
SCL
PsA
MIC
COL
CAE
CrA
LUP
SCO
PHE
GRU
Moon phases
Dawn
Midnight
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
30
29

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

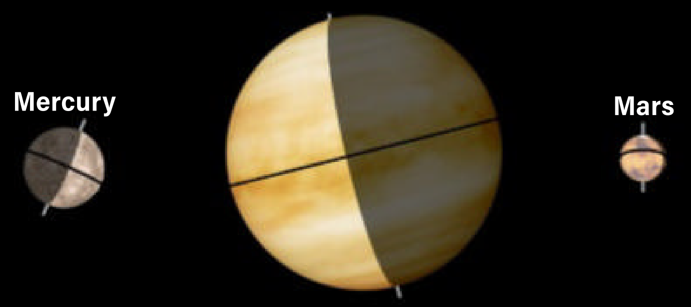
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.


Jupiter
Uranus
Saturn
Neptune
Pluto


Jupiter
Venus
Greatest eastern elongation is June 4
Mars
Mercury
Ceres
Earth
Summer solstice is June 21

THE PLANETS IN THE SKY

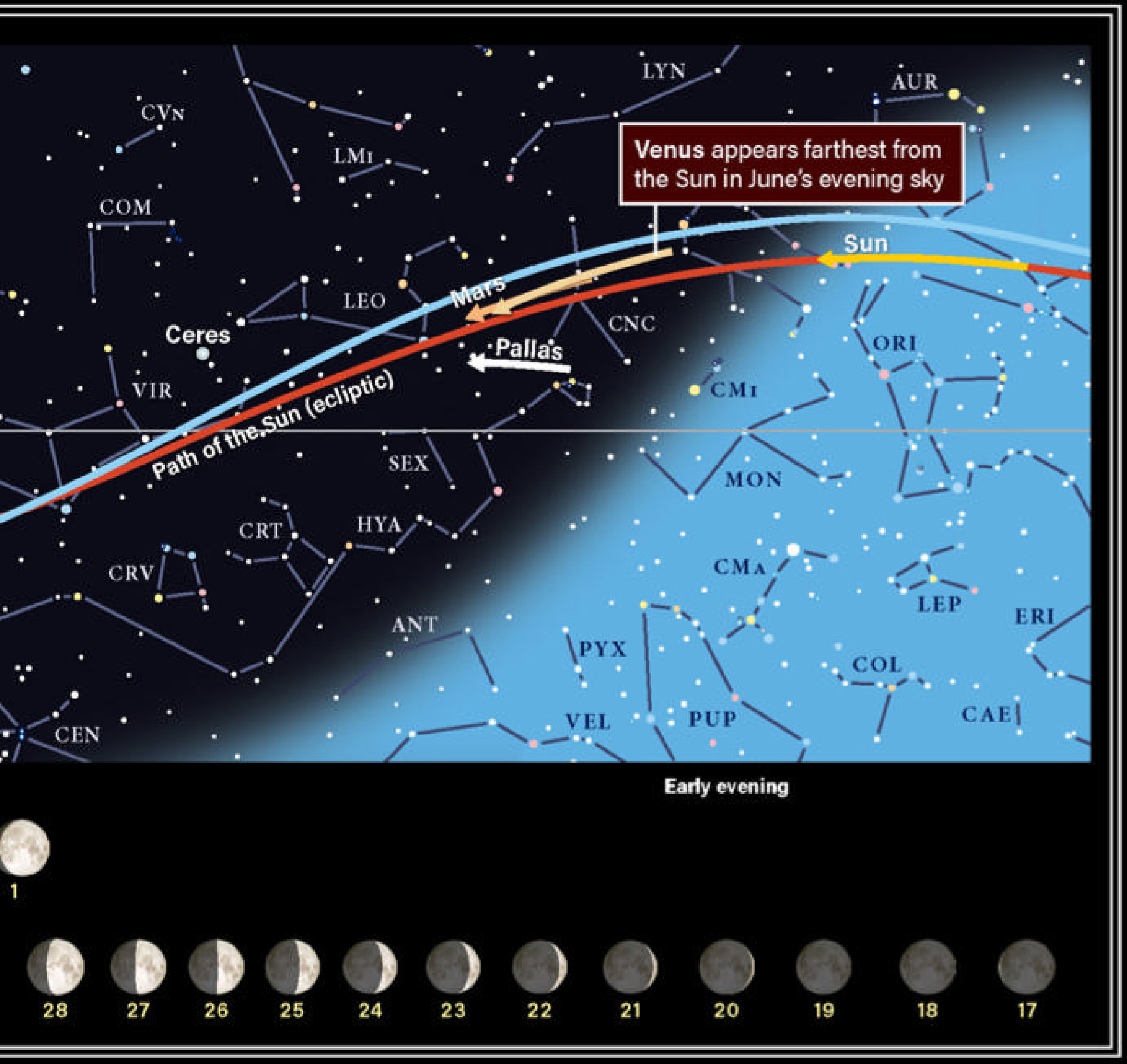
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.


Mercury
Mars

PLANETS	MERCURY	VENUS
Date	June 1	June 15
Magnitude	0.4	–4.5
Angular size	7.8"	26.7"
Illumination	44%	43%
Distance (AU) from Earth	0.868	0.624
Distance (AU) from Sun	0.427	0.724
Right ascension (2000.0)	2h56.2m	8h44.9m
Declination (2000.0)	13°14'	20°08'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

JUNE 2023



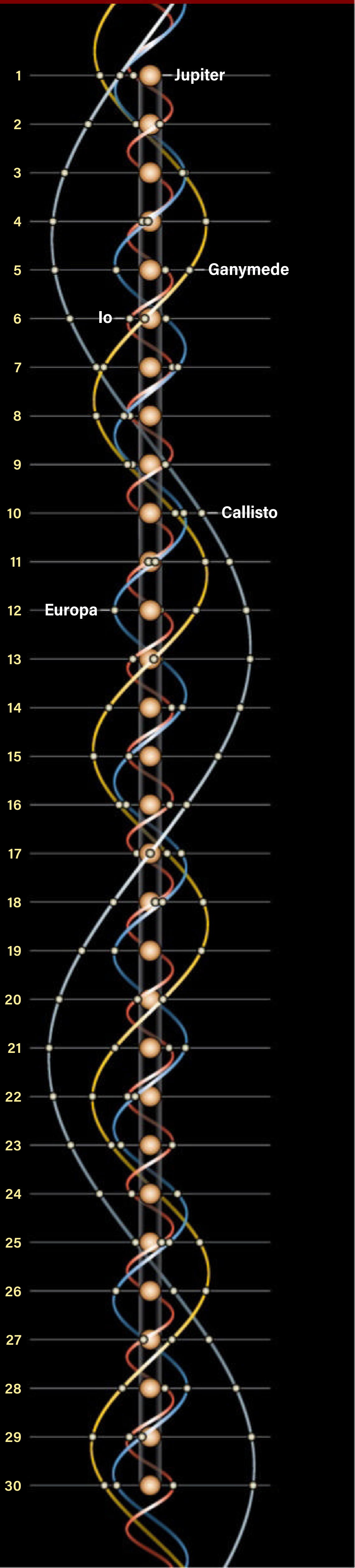
LYN
AUR
CVN
LMI
COM
Venus appears farthest from the Sun in June's evening sky
Sun
LEO
Mars
Ceres
CNC
Pallas
ORI
VIR
CMI
Path of the Sun (ecliptic)
SEX
MON
CRT
HYA
CMA
CRV
LEP
ERI
ANT
PYX
COL
CEN
VEL
PUP
CAE
1
28
27
26
25
24
23
22
21
20
19
18
17

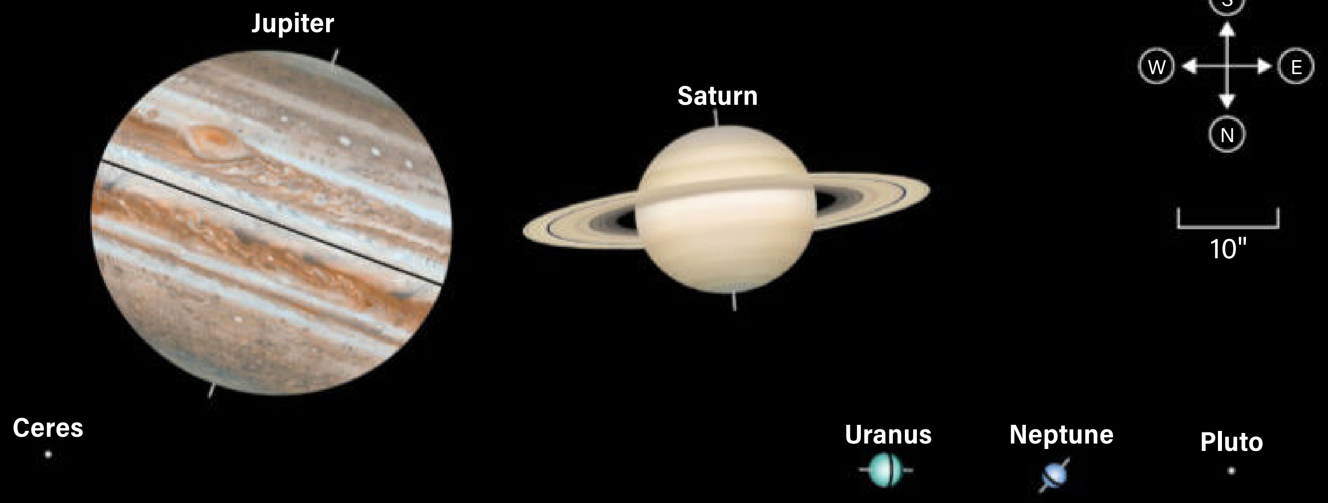
Early evening

Callisto
Europa
Io
Ganymede

JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 A.M. EDT on the date shown. South is at the top to match the view through a telescope.





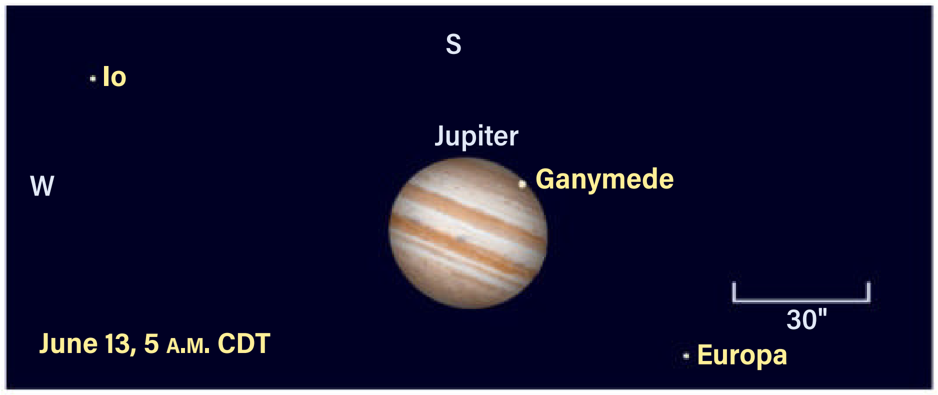
Jupiter
Saturn
S
W
E
N
10"
Ceres
Uranus
Neptune
Pluto

MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
June 15	June 15	June 15	June 15	June 15	June 15	June 15
1.7	8.4	–2.1	0.7	5.9	7.8	15.1
4.5"	0.6"	35.3"	17.6"	3.4"	2.3"	0.1"
94%	96%	99%	100%	100%	100%	100%
2.104	2.322	5.588	9.456	20.492	29.961	33.965
1.665	2.610	4.957	9.793	19.645	29.909	34.788
9h09.1m	12h09.7m	2h16.2m	22h36.8m	3h13.1m	23h52.0m	20h09.5m
17°48'	10°07'	12°28'	–10°27'	17°36'	–2°12'	–22°47'

SKY THIS MONTH

— *Continued from page 29*

Southern trek



Ganymede's transit on June 13 shows off the tilt of the Galilean moons' orbital plane relative to Earth. Callisto (not shown) is located farther east.

This is because at this point in Iapetus' nearly 80-day orbit, its brighter hemisphere is facing Earth. Prior to elongation, Iapetus passes 34" north of Saturn on the morning of June 3. On the following morning, it stands 18" east of bright Titan before dawn, enabling easy identification of the fainter (magnitude 11) Iapetus. You can then follow it westward as it increases its separation from Saturn, reaching 9' by the 24th.

Neptune stands 20° above the eastern horizon around 4:30 A.M. local time as June opens. It lies about 20° east of Saturn, just across the border from Aquarius in southwestern Pisces. If you can easily spot the Circlet of Pisces due south of the Square of Pegasus, then you can find Neptune 4.5° southeast of 4th-magnitude Lambda (λ) Piscium.

You'll need binoculars to spot this remote planet. Shining at magnitude 7.8, it forms a neat triangle with 5th-magnitude 20 Piscium and 6th-magnitude 24 Piscium. These two stars are part of a trio that lie in a straight line spanning about 3°. The brightest is 5th-magnitude 27 Piscium at the eastern end of the line.

By June 25, Neptune's easterly motion slows almost to a halt and the planet stands about 1° north of 24 Piscium for about three weeks with little sign of motion relative to the background stars.

Jupiter has arrived in Aries the Ram. The giant planet rises just before 4:00 A.M. local time on June 1 and about two hours earlier on June 30. Its brightness increases slightly from magnitude –2.1 to –2.2, making it easy to spot over the eastern horizon before dawn. Catch the waning crescent Moon sitting less than 3° east of Jupiter on the morning of June 14.

Observing Jupiter is a challenge in early June due to its low altitude at the onset of twilight. Things steadily improve as the month progresses. On June 30, Jupiter stands 30° high in the east as twilight begins. This offers a short period to observe the planet as it climbs above the haze and turbulence of our own atmosphere. Check the state of its dark belts and bright zones.

The Galilean satellites — Io, Europa, Ganymede, and Callisto — orbit Jupiter in its equatorial plane. The current tilt relative to Earth causes Callisto to miss passing in front of the planet. The remaining three moons transit or are occulted by Jupiter's disk from time to time. The observing window is narrow, but there are a few interesting events this month.

On June 11, several observable events occur. As Jupiter rises on the East Coast, there's a shadow on the disk; it belongs to Io, approaching the eastern limb. By the time Jupiter clears the horizon in the Midwest, Io is transiting between two shadows: its own to the west and Europa's to the east. Meanwhile, Europa itself is east of the disk. Io's transit ends just before 4:40 A.M. CDT. Within 10 minutes, Europa begins a transit. Note the relative position of

WHEN TO VIEW THE PLANETS

EVENING SKY
Venus (west)
Mars (west)

MIDNIGHT
Mars (west)
Saturn (east)

MORNING SKY
Mercury (east)
Jupiter (east)
Saturn (south)
Uranus (east)
Neptune (southeast)

COMET SEARCH | Under her wing

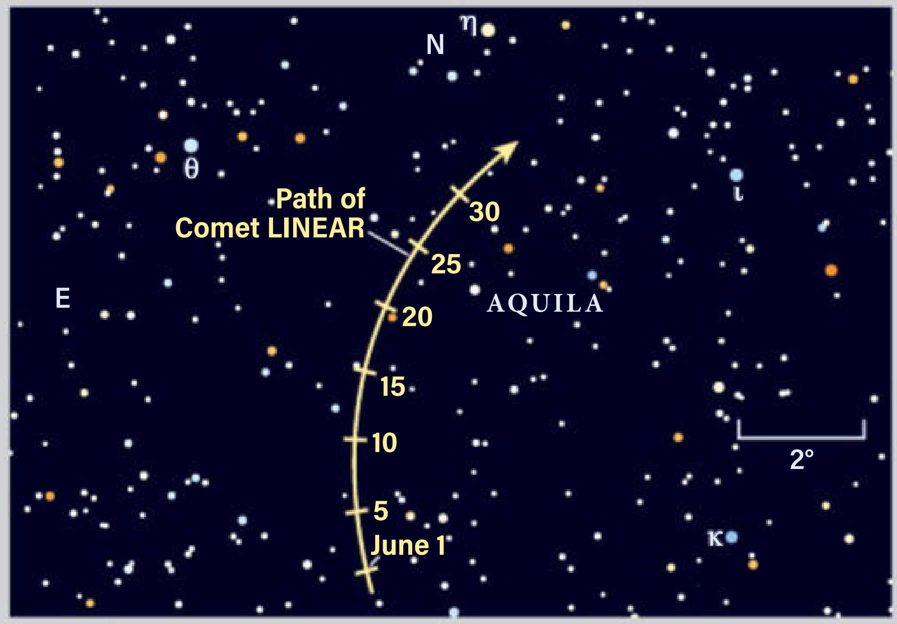
AFTER A SPRING SKY full of galaxies and globular clusters, you're ready for a faint gray cotton ball of another type. A small comet is slowly gliding up eastern Aquila. The 237th comet to be recognized as periodic, this one remains beyond Mars' orbit and never brightens to binocular range.

Use a 10-inch scope under a dark sky to visually detect 237P/LINEAR, or pick it up its 11th- to 12th-magnitude glow with a telephoto lens on a star-tracker. It should be quite round, as its feeble tail is stretched out behind the compact coma.

Discovered in 2002 by the prolific Lincoln Laboratory Near-Earth Asteroid Research (LINEAR) program, 237P is a Jupiter-family comet. Its 6.6-year orbit gives us one chance every 20 years to see it at its best.

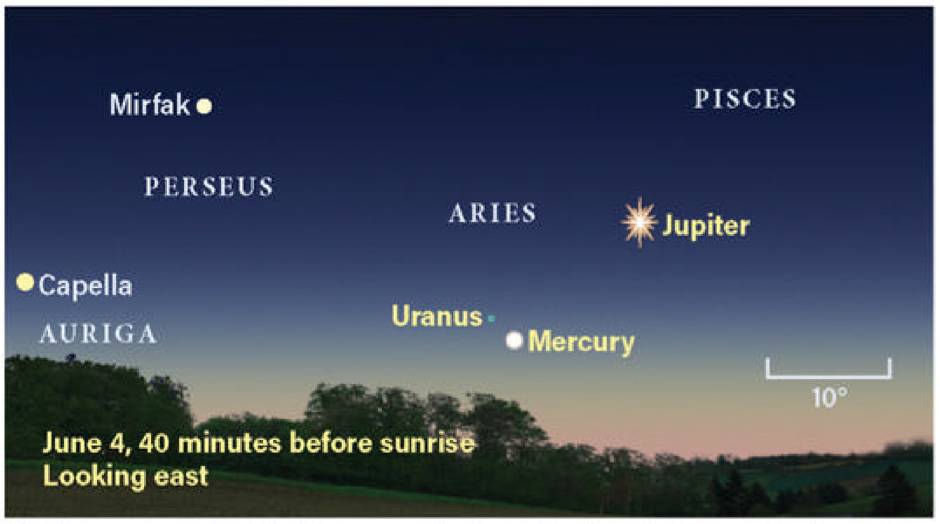
Observers south of the equator can also easily catch 9th-magnitude C/2021 T4 (Lemmon) before dawn.

Comet 237P/LINEAR



While we wait for a short-notice brighter comet, with your bare eyes follow the light cycle of the star Eta [η] Aquilae (at top). Surprise yourself with how easy it is to watch Eta fade from magnitude 3.5 down to 4.3 and back again in a week's time.

Look and find



Challenge yourself to find Uranus with binoculars just before sunrise in early June. Though low, naked-eye Mercury can point the way.

Europa and its shadow and you get a sense of the direction the Sun is shining relative to our view. Europa's shadow leaves around 5:10 A.M. CDT, as twilight floods the Midwest. Pacific Coast observers will see much of Europa's transit.

The giant moon Ganymede transits Jupiter's southern polar region June 13 between 4:47 A.M. and 6:44 A.M. CDT. Its path is indicative of the tilt of the moons' orbital plane. The transit technically starts several minutes earlier; the slow-moving moon takes more than 10 minutes to fully move onto the disk of Jupiter.

The tilt of the orbital plane is emphasized again the morning of June 17, when Callisto stands due south of Jupiter.

Io and its shadow transit early on June 18. The eastern half of the country will see the shadow transit starting around 4:25 A.M. EDT, followed by the moon itself just over an hour later at 5:28 A.M. EDT. The western U.S. will see Europa's shadow begin a transit at 3:26 A.M. PDT. Some of these events are affected by twilight, depending on your geographic location.

There's a narrow window to spot **Uranus** before twilight encroaches. The planet lies about 16° east of Jupiter. It, too, is in Aries, just 10° southwest of the Pleiades (M45) in Taurus. Uranus shines at magnitude 5.9 and requires binoculars to spot.

The ice giant is 1.6° southwest of the waning crescent Moon on June 15 — but catch it shortly after moonrise, say around 3:50 A.M. local time, before the oncoming twilight.

Uranus lies about 2° from 4th-magnitude Delta (δ) Arietis. Catch the planet wandering south of Delta in late June before twilight hides them.

On June 1, **Mercury** is just three days past greatest elongation. It rises less than an hour after Jupiter and is 13° east of the giant planet. As its elongation from the Sun decreases, Mercury brightens from magnitude 0.4 on the 1st to magnitude −1.0 on June 19.

On June 4, can you catch Uranus 3° due north of Mercury? It's a challenging observation, aided by viewing with binoculars from higher elevations. The fast-approaching twilight will quickly hide the more distant planet. Mercury stands 4° above the horizon 40 minutes before sunrise.

Mercury reaches magnitude −0.2 on June 10, when it is 7° south of M45, whose stars are faintly visible in twilight. On June 16, a waning crescent Moon hangs less than 5° above Mercury's location; the magnitude −0.7 planet is now so low that it is challenging to spot. As the sky brightens, try to see Aldebaran 4.5° southeast of Mercury. Equatorial and Southern Hemisphere observers will have a better chance.

Mercury quickly disappears from view even as it brightens, growing too close to the Sun for observation late in the month. It reaches superior conjunction as July begins.

The summer solstice occurs June 21 at 11 A.M. EDT. This marks the date when the Sun is at its northernmost declination.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling***, who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

LOCATING ASTEROIDS |

Mom comes for a visit

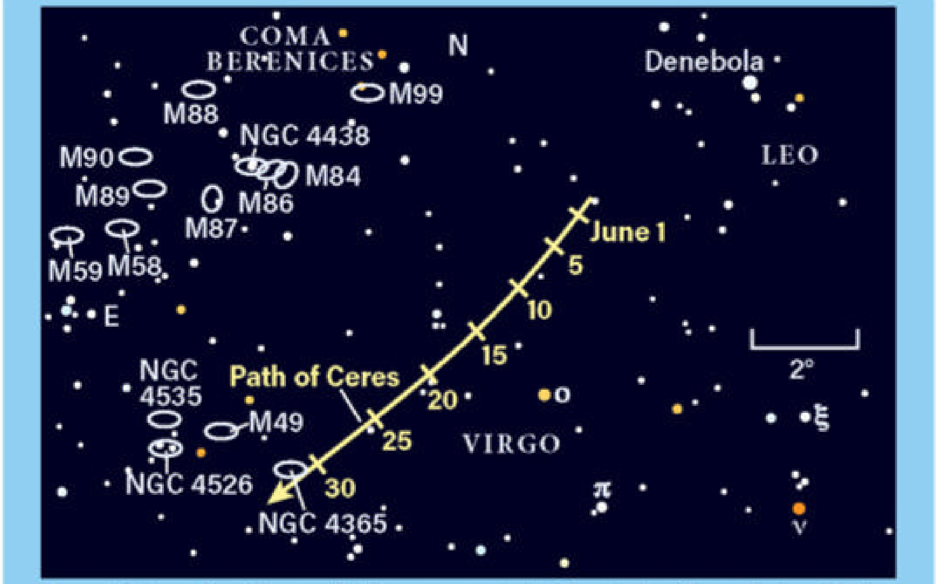
OUR EYES DRAW US along the line from Venus and Mars through blue-white Regulus to sparkling Spica. Pop up a bit to 2nd-magnitude Denebola, the tail of Leo, and its fainter companion Omicron (ο) Virginis in the head of Virgo. The Virgin is sometimes said to depict the Greek maiden Persephone, whose mother was Demeter (called Ceres by the Romans).

It is here we seek the celestial maiden's mother. The reigning queen of the main belt, 1 Ceres spans 600 miles but is fading past 8th magnitude as it falls behind speedier Earth. Any small telescope will readily pick up the dot of light from the suburbs, all the easier this month thanks to the sparse star fields and their simple patterns that won't confuse.

To note a shift from night to night, simply place four stars inside a circle in your logbook, using an eyepiece that shows about a degree (or twice the apparent diameter of the Full Moon). Return an evening or two later and note the one that moved. The best night to see Ceres move in just a couple of hours is the 6th, when it closes in on a slightly fainter star. Avoid June 23 to 27 altogether, when the Moon is nearby.

If you're at a dark site finding Messier galaxies, you can simply slide northwest from M49 to pick up the easier Ceres.

Deep-sky delights



Ceres is traveling through Virgo, a constellation rich with galaxies. Only objects brighter than magnitude 10 are shown here.

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

Explore the 10

Take a trip around the galactic block and get to know your stellar neighbors.

BY STEPHEN ORNES

IF YOU WANT TO STUDY THE STARS, there's no better place to start than close to home. After all, the nearest star is just 93 million miles (150 million kilometers) away: the Sun. Its daily presence and predictable motions through the sky may make it seem like a boring, steady companion. But up close, it's an incendiary tempest of roiling plasma, erupting with brilliant solar flares and mottled by darker sunspots — not to mention it's the only star known (so far) to host a planetary system that includes an inhabited world.

An estimated 200 billion trillion or so stars fill the known cosmos, but nearby stars attract a lot of attention from astronomers. "We are somehow attached naturally to things that are close by, to finding out what's going on right next door," says astronomer Rodrigo Díaz at the National University of San Martín in Buenos Aires, Argentina, who has helped discover planets that orbit nearby stars. "We grow up in a neighborhood, and as we grow, we expand our sphere of familiarity and go bigger and bigger and bigger."

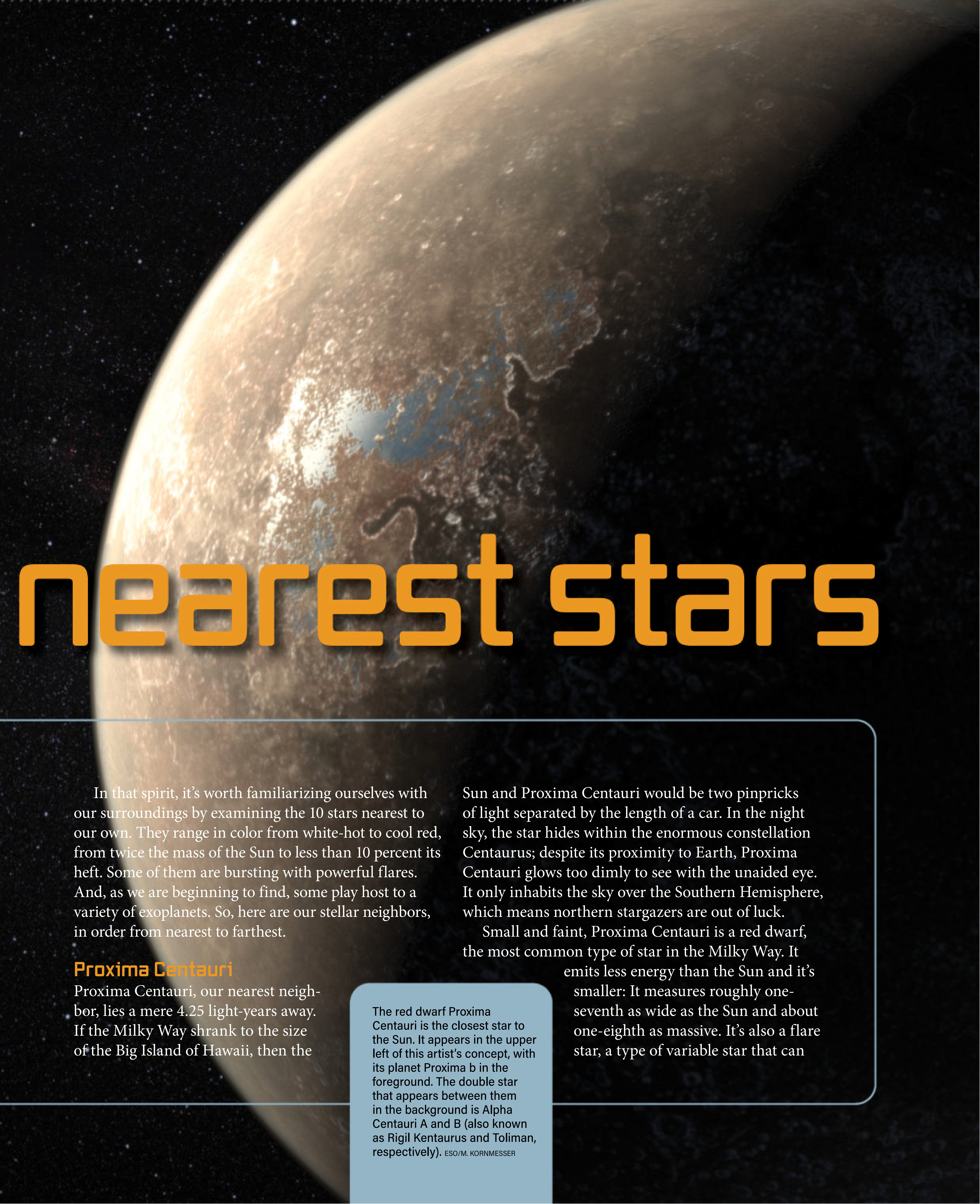
nearest stars

In that spirit, it's worth familiarizing ourselves with our surroundings by examining the 10 stars nearest to our own. They range in color from white-hot to cool red, from twice the mass of the Sun to less than 10 percent its heft. Some of them are bursting with powerful flares. And, as we are beginning to find, some play host to a variety of exoplanets. So, here are our stellar neighbors, in order from nearest to farthest.

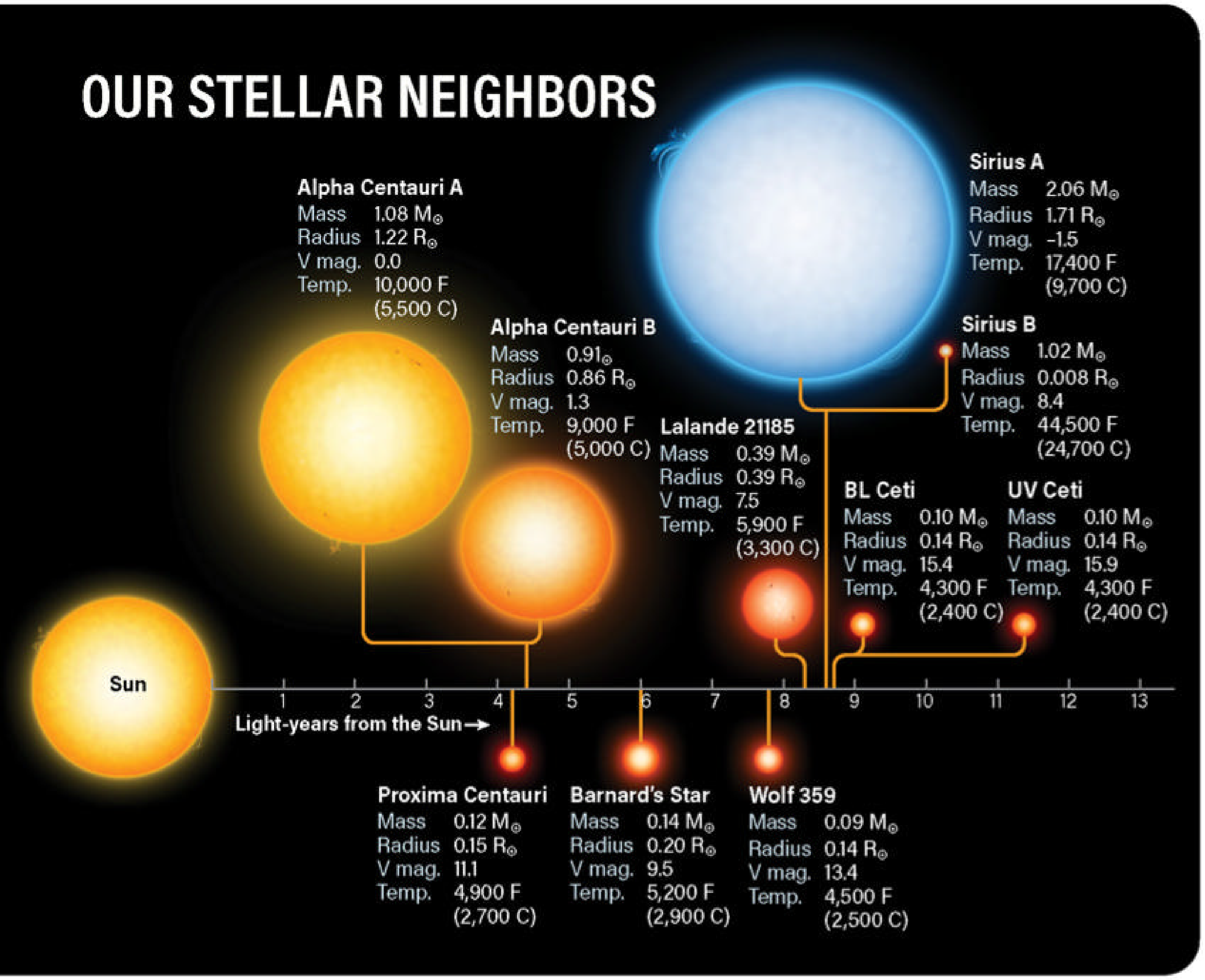
Proxima Centauri

Proxima Centauri, our nearest neighbor, lies a mere 4.25 light-years away. If the Milky Way shrank to the size of the Big Island of Hawaii, then the Sun and Proxima Centauri would be two pinpricks of light separated by the length of a car. In the night sky, the star hides within the enormous constellation Centaurus; despite its proximity to Earth, Proxima Centauri glows too dimly to see with the unaided eye. It only inhabits the sky over the Southern Hemisphere, which means northern stargazers are out of luck.

Small and faint, Proxima Centauri is a red dwarf, the most common type of star in the Milky Way. It emits less energy than the Sun and it's smaller: It measures roughly one-seventh as wide as the Sun and about one-eighth as massive. It's also a flare star, a type of variable star that can



The red dwarf Proxima Centauri is the closest star to the Sun. It appears in the upper left of this artist's concept, with its planet Proxima b in the foreground. The double star that appears between them in the background is Alpha Centauri A and B (also known as Rigil Kentaurus and Toliman, respectively). ESO/M. KORNMESSER

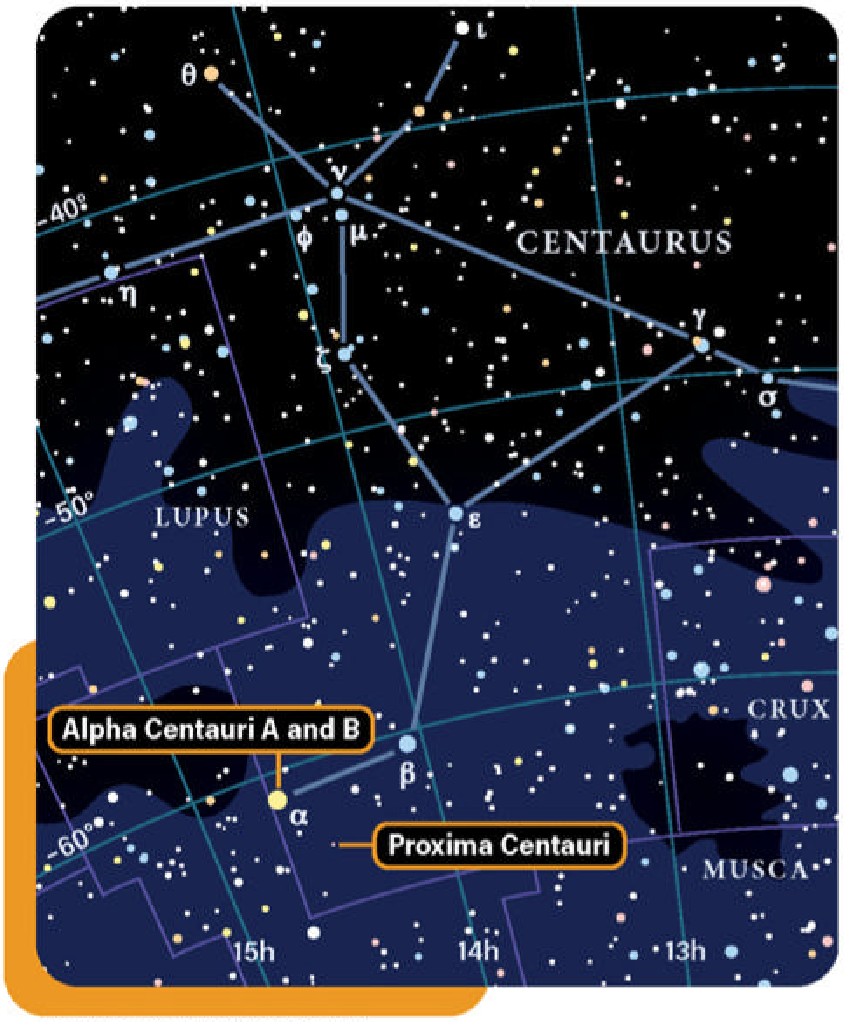

OUR STELLAR NEIGHBORS
Alpha Centauri A
Mass 1.08 M⊙
Radius 1.22 R⊙
V mag. 0.0
Temp. 10,000 F (5,500 C)
Alpha Centauri B
Mass 0.91⊙
Radius 0.86 R⊙
V mag. 1.3
Temp. 9,000 F (5,000 C)
Sirius A
Mass 2.06 M⊙
Radius 1.71 R⊙
V mag. -1.5
Temp. 17,400 F (9,700 C)
Sirius B
Mass 1.02 M⊙
Radius 0.008 R⊙
V mag. 8.4
Temp. 44,500 F (24,700 C)
Lalande 21185
Mass 0.39 M⊙
Radius 0.39 R⊙
V mag. 7.5
Temp. 5,900 F (3,300 C)
BL Ceti
Mass 0.10 M⊙
Radius 0.14 R⊙
V mag. 15.4
Temp. 4,300 F (2,400 C)
UV Ceti
Mass 0.10 M⊙
Radius 0.14 R⊙
V mag. 15.9
Temp. 4,300 F (2,400 C)
Sun
1 2 3 4 5 6 7 8 9 10 11 12 13
Light-years from the Sun→
Proxima Centauri
Mass 0.12 M⊙
Radius 0.15 R⊙
V mag. 11.1
Temp. 4,900 F (2,700 C)
Barnard's Star
Mass 0.14 M⊙
Radius 0.20 R⊙
V mag. 9.5
Temp. 5,200 F (2,900 C)
Wolf 359
Mass 0.09 M⊙
Radius 0.14 R⊙
V mag. 13.4
Temp. 4,500 F (2,500 C)

unpredictably and violently shine brightly for short periods of time, sometimes as brief as a few minutes.

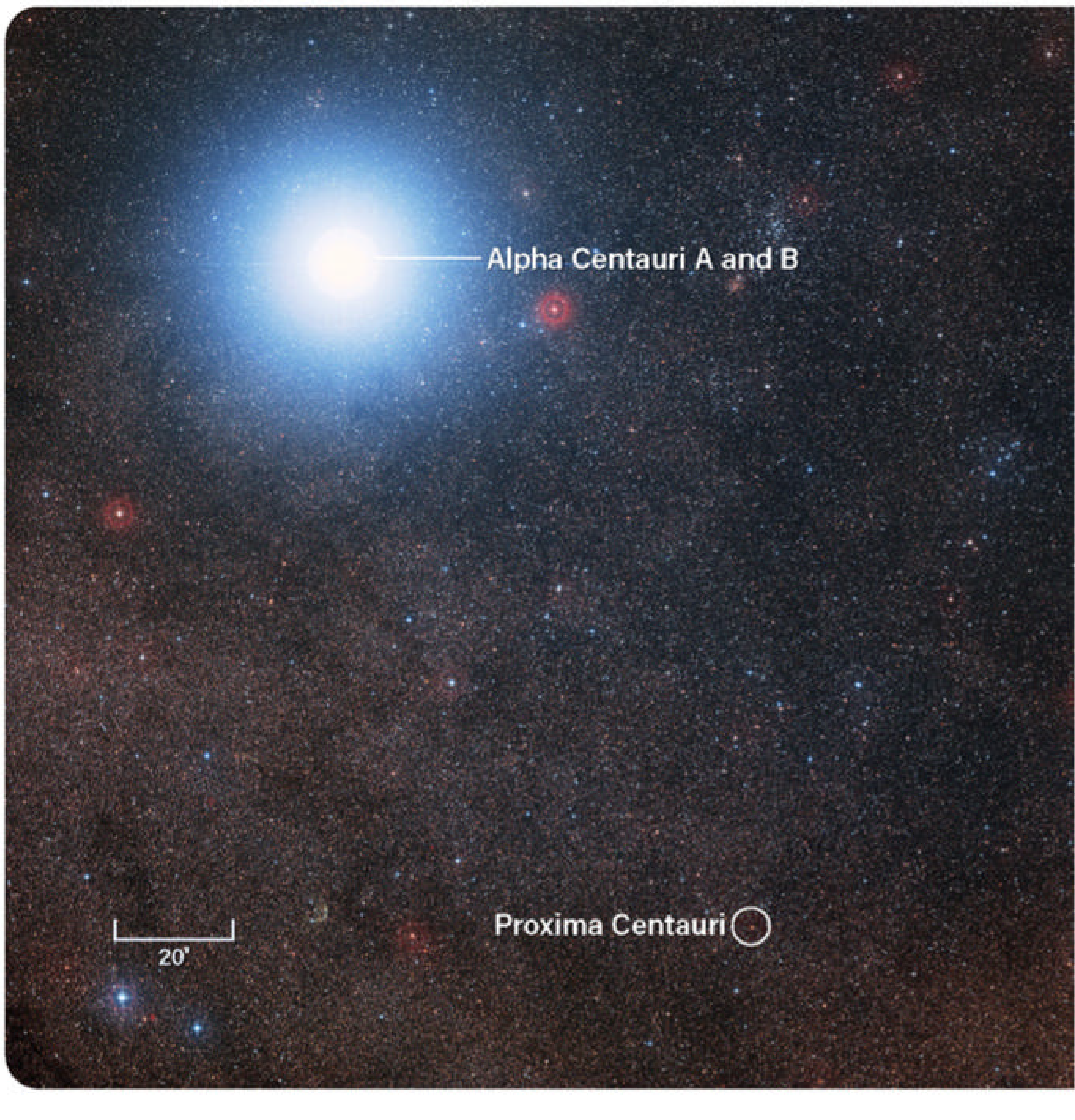
Those bright flares mean that it's unlikely to host a habitable world. So far, astronomers have confirmed one planet in its orbit. Proxima b, discovered in 2016 and confirmed in 2020, is a rocky world about 7 percent more massive than Earth. It orbits in the habitable zone, the right distance from its star for its surface to support liquid water. But that doesn't

LEFT: Our Sun and its 10 nearest neighbors are shown in this diagram with their relative sizes to scale. Their masses and radii are given in solar masses (M⊙) and solar radii (R⊙); magnitudes listed are visual (V) magnitudes. *ASTRONOMY*: ROEN KELLY

BELOW: Proxima Centauri and Alpha Centauri A and B are so close to us that although they are gravitationally bound to each other, they lie over 2° apart on the sky — equivalent to four times the width of the Full Moon. DIGITIZED SKY SURVEY 2; ACKNOWLEDGEMENT: DAVIDE DE MARTIN/MAHDI ZAMANI

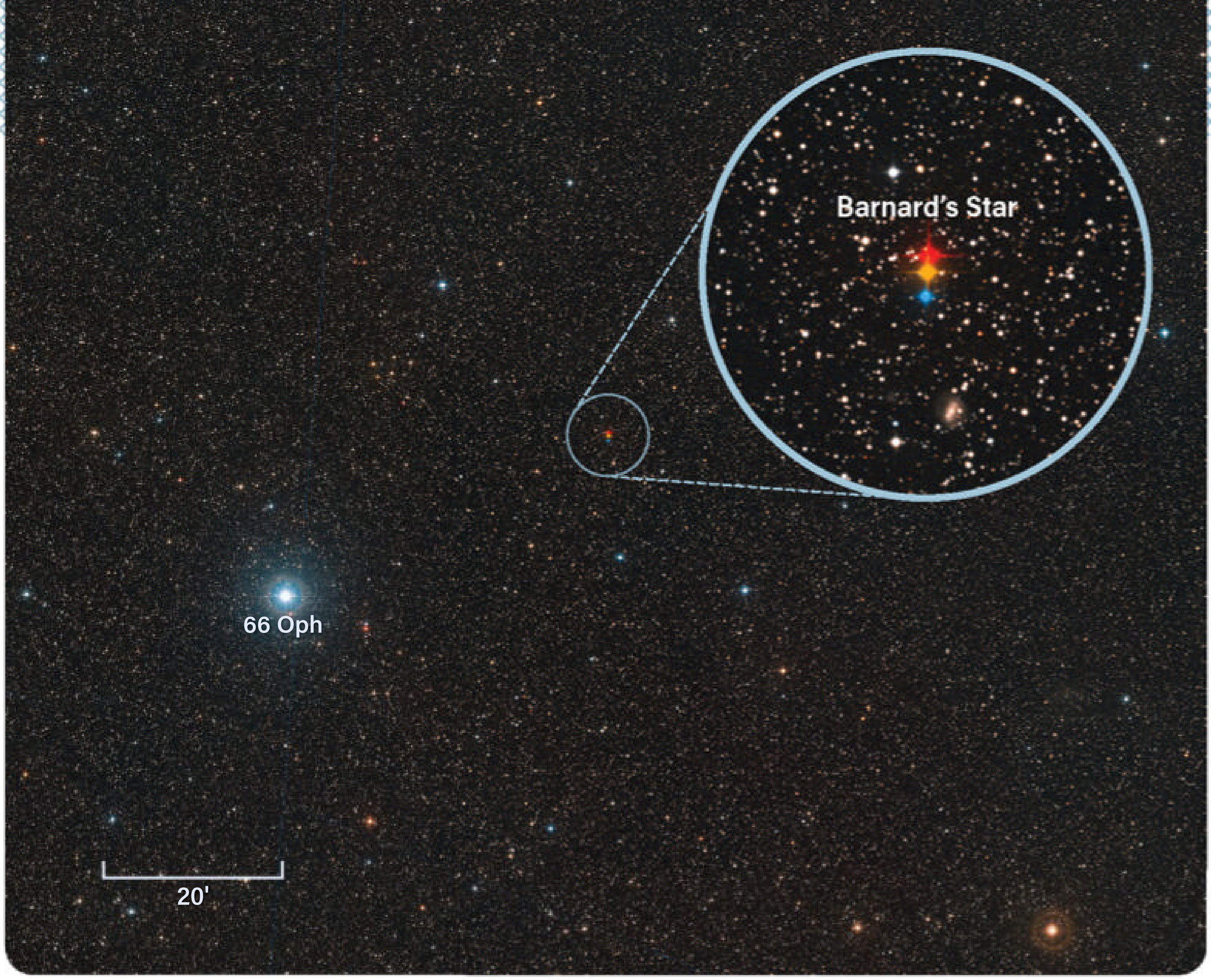

θ
ι
ν
φ
μ
-40°
η
CENTAURUS
γ
σ
ζ
-50°
LUPUS
ε
CRUX
Alpha Centauri A and B
β
α
Proxima Centauri
-60°
MUSCA
15h
14h
13h

ALL STAR CHARTS: *ASTRONOMY*: ROEN KELLY

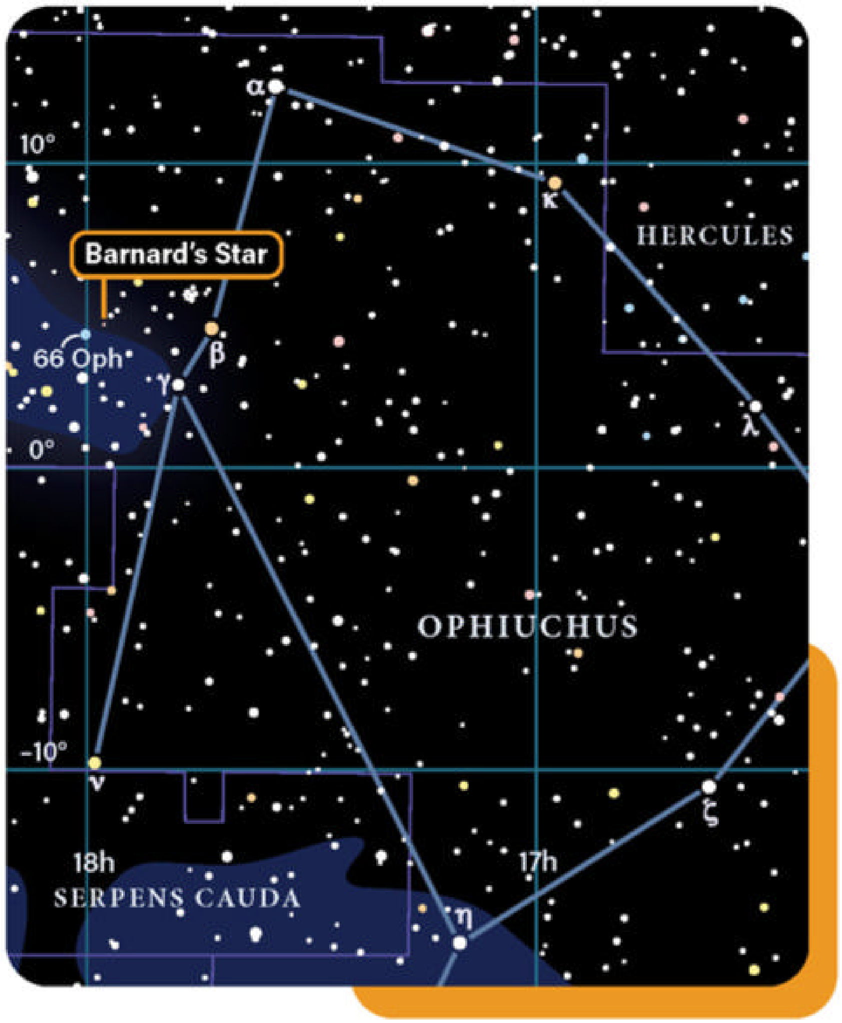

Alpha Centauri A and B
Proxima Centauri
20'

mean the planet is habitable: In 2018 the star released a powerful electromagnetic flare. If such flares were common in its past, they could have obliterated anything alive — as well as any atmosphere — on the planet.

Candidate planet Proxima c, which was discovered in 2020, orbits father out and is about six times as massive as Earth. It's too far from the star to host liquid water. And in February 2022, astronomers reported the signature of a third possible planet, with only a quarter the mass of Earth and so close that it orbits the star every five days.



ABOVE: Barnard's Star has the fastest known proper motion across the night sky of any star, traversing an angular distance equivalent to the width of the Full Moon roughly every 180 years. Three different exposures of the star — shown in red, yellow, and blue — show its movement against the background stars. ESO/DIGITIZED SKY SURVEY 2; ACKNOWLEDGEMENT: DAVIDE DE MARTIN; E — RED DOTS



The Alpha siblings

Proxima Centauri isn't a solo star — it's actually the outlier in a three-star system. Its binary companions, Alpha Centauri A and B, orbit their mutual center of gravity every 80 years. They're about 4.35 light-years from Earth and separated from each other by about 23 times the average distance between the Sun and Earth (or about the distance from the Sun to Uranus).

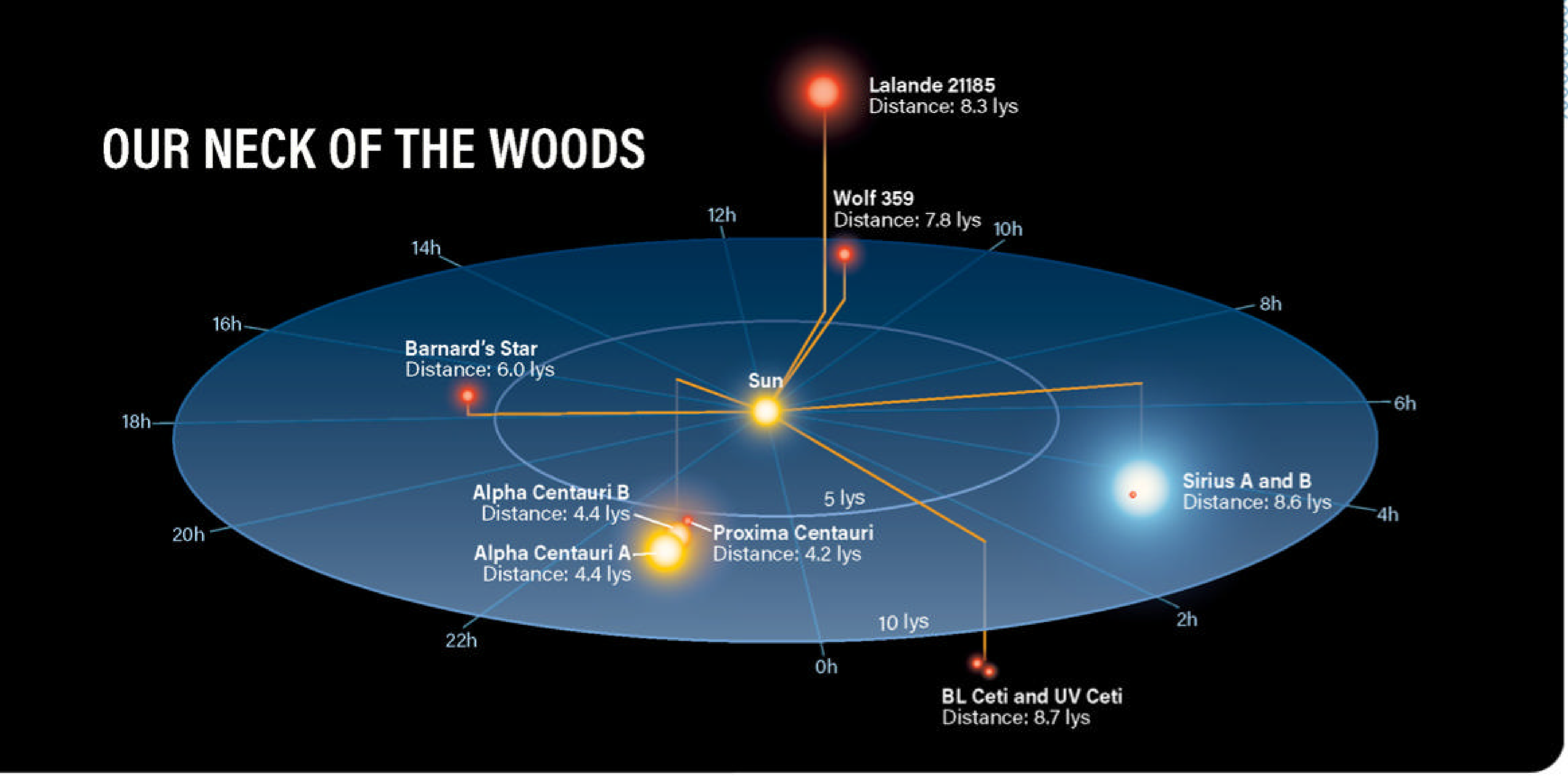
Alpha Centauri, though, is no longer the system's official name. In 2016, the International Astronomical Union (IAU) officially renamed Alpha Centauri A to Rigil Kentaurus — based on its ancient Arabic name, which means "foot of the Centaur." (Like Proxima, the star is found in the constellation Centaurus.) It is the larger of the two Alpha Centauri stars and the most Sun-like. It has about 10 percent more mass than the Sun and burns bright yellow. Like the Sun, it is classified as a G2 star and has a surface temperature around 10,000 degrees Fahrenheit (5,500 degrees Celsius).

Its companion star, commonly known as Alpha Centauri B, became Toliman under the IAU's naming shift of 2016. Toliman is about 10 percent less massive than the Sun and, as a K-type star, glows more orange than yellow. Together, Rigil Kentaurus and Toliman shine as one star and are observable to the naked eye as the third-brightest light in the night sky. With the aid of a telescope, the two can be distinguished from each other.

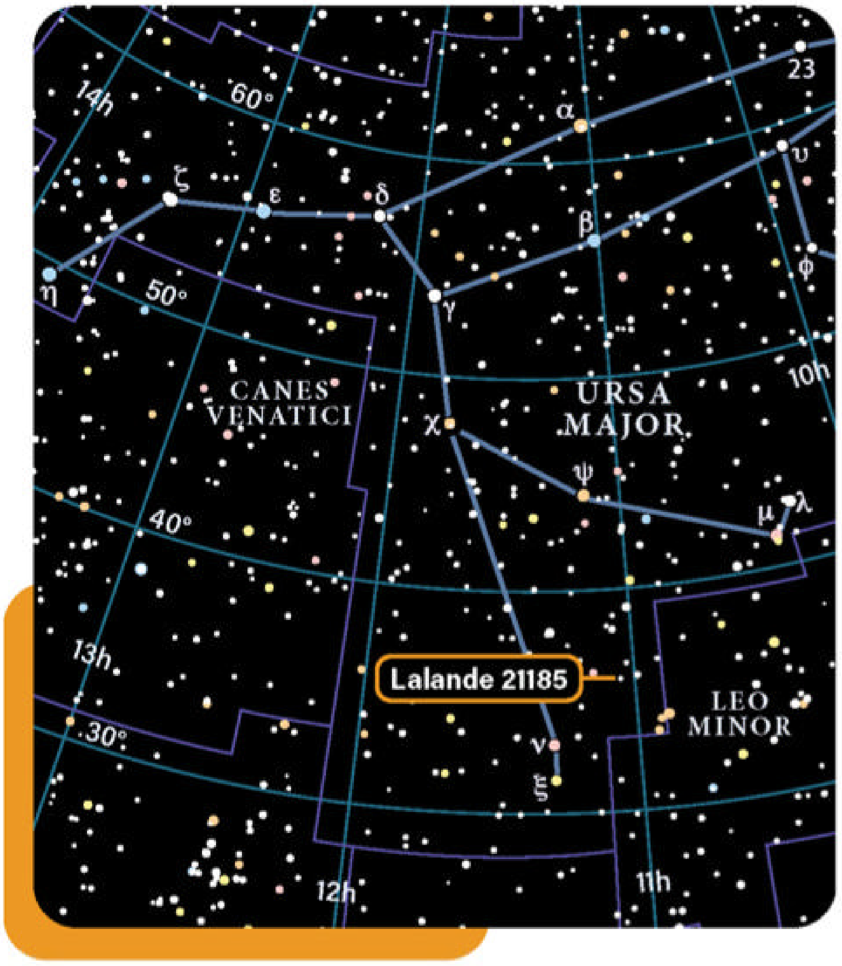
No planets have been confirmed orbiting The Stars Formerly Known As Alpha Centauri, but in March 2022 astronomers published a model of what an Earth-sized planet *might* look like in the system's habitable zone. Their calculations yielded a world similar to Earth in water content but richer in carbons like graphite and diamond, and with a larger iron core and perhaps less plate tectonic activity.

The runaway star

The next closest star, at about 6 light-years away in Ophiuchus, is Barnard's Star. The star is famous not so much for its composition — it's a rather small and humdrum red dwarf, like the vast majority of stars — but for its locomotion. Barnard's Star has the unique distinction of being the fastest-moving star in the sky, a trait first observed by its discoverer, American astronomer Edward Emerson Barnard. It


OUR NECK OF THE WOODS
Lalande 21185
Distance: 8.3 lys
Wolf 359
Distance: 7.8 lys
12h
10h
14h
8h
16h
Barnard's Star
Distance: 6.0 lys
Sun
18h
6h
Alpha Centauri B
Distance: 4.4 lys
5 lys
Sirius A and B
Distance: 8.6 lys
4h
20h
Proxima Centauri
Distance: 4.2 lys
Alpha Centauri A
Distance: 4.4 lys
10 lys
2h
22h
0h
BL Ceti and UV Ceti
Distance: 8.7 lys

ABOVE: Stars are plotted in 3D in this map, with one line extending radially from the Sun in the plane of the celestial equator and a vertical line showing how far above or below that plane the star is. Distances are given in light-years. *ASTRONOMY:* ROEN KELLY


14h
60°
23
α
ζ
ε
δ
υ
β
η
50°
φ
γ
CANES VENATICI
URSA MAJOR
10h
χ
ψ
μ
λ
40°
13h
Lalande 21185
LEO MINOR
30°
ν
ξ
12h
11h

appears to move across the sky — a behavior astronomers call proper motion — at a rate of 10.4" every year as it zips through space at 310,000 mph (500,000 km/h).

Like Proxima Centauri, Barnard's Star is a flare star. It's several billion years old and has a radius one-fifth that of the Sun. Whether the star has a planetary system remains an open question and the subject of a decades-long tug of war in the astronomical community. In the 1960s, Dutch astronomer Peter van de Kamp claimed to have found evidence for two giant, Jupiter-like worlds: Images of the star taken through repeated telescopic observations hinted at wiggles and shivers that suggest the gravity of a nearby planet was tugging on it. But this was dismissed in the 1970s as instrument error when a review of van de Kamp's photographic plates found that *all* of the stars in that field of view appeared to wobble in the same way at the same time, corresponding to upgrades to the telescope. A 2018 study claimed strong evidence for a super-Earth, but in 2021 astronomers reported they failed to find a convincing signal.

Science fiction writers certainly want it to be true. Since the 1930s, Barnard's Star and its phantom planets have figured in books, movies, and video games, including *The Hitchhiker's Guide to the Galaxy.*

A wolf in star's clothing

The next nearest star is the red dwarf Wolf 359, which has also been name-checked prominently in science fiction. In an episode of *Star Trek: The Next Generation*, the Battle of Wolf 359 resulted in the destruction of dozens of Federation ships by the Borg.

Wolf 359 is a red dwarf in the constellation Leo, about 7.9 light-years away. Despite its proximity, it remains undetectable to the naked eye. It's one of the smallest stars known — closer in diameter to Jupiter than to the Sun. Like Proxima Centauri and Barnard's Star, it occasionally flares brightly, and like Barnard's Star, it moves across the sky with a high proper motion. It was first identified by German astronomer Max Wolf in his catalog of over 1,000 fast-moving stars. The star doesn't have enough mass to swell and become a red giant, and

> In an episode of *Star Trek: The Next Generation*, the Battle of Wolf 359 resulted in the destruction of dozens of Federation ships by the Borg.

models suggest that it's fully convective, which means heat from the center moves all the way to the surface, conveyed by giant masses of plasma.

In 2019, planet hunters searching hundreds of nearby red dwarfs identified two possible worlds in orbit around Wolf 359. One is a cool super-Neptune that orbits once every 2,938 days. The other candidate, closer in, was thought to be a hot super-Earth with a period of only 2.69 days, but subsequent observations have called that planet into question.

Long-sought worlds

Lalande 21185 is one of the brightest red dwarfs close to Earth — though, like others of its kind, it's still too dim to see with the naked eye. At 8 light-years away, it can be found in the southern part of Ursa Major, and measures a little less than half as large as the Sun in both diameter and in mass. Jérôme Lalande, an 18th-century French astronomer who largely assembled vast catalogs of planetary positions, discovered the star.

It's also known as Gliese 411, its designation in the Gliese star catalog. Astronomers have floated claims that the star harbors its own planetary system at least since the 1950s, when Peter van de Kamp and his student Sarah Lippincott reported wobbles in its motion. These were subject to the same instrument error as van de Kamp's discredited reports of planets around Barnard's Star. Separately, in the 1990s, astronomer George Gatewood predicted a planet with 90 percent the mass of Jupiter. But that, too, has not been borne out.

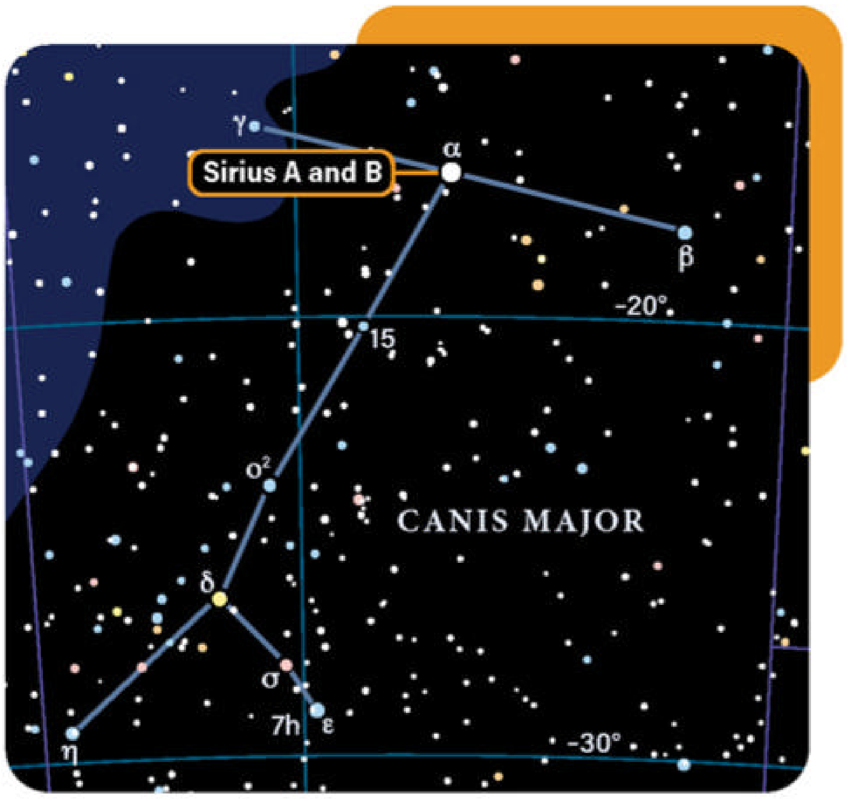
In May 2019, astronomers including Rodrigo Díaz described new evidence for a super-Earth around Lalande 21185 that orbits about every 13 days and is likely far too hot to be habitable. And in April 2022, astronomers reported evidence for a Neptune-like planet with an orbit of about eight years. (They also described data suggesting a third planet may orbit the star with a period of 215 days.)

Díaz, who helped find that world, says its proximity makes it a tantalizing target for future observing missions. New, enormous telescopes with mirrors larger than 20 meters in diameter are now under construction — including the Extremely Large Telescope and Giant Magellan Telescope, both in Chile — that will have the ability to directly image such worlds and probe their atmospheres.

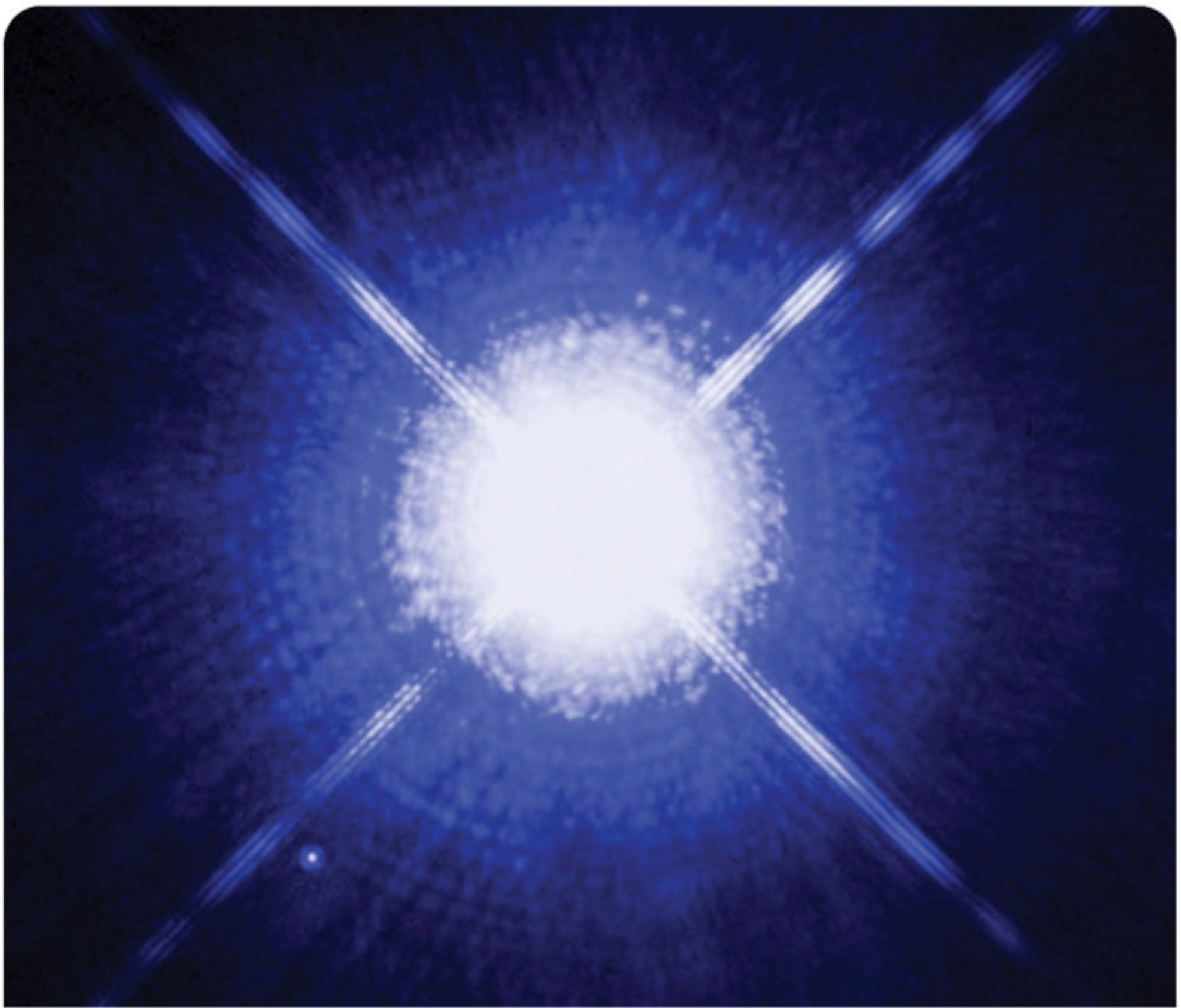
Seriously bright

There may be no star more famous than Sirius A, the brightest star in the sky. It boasts a luminosity more than 25 times that of the Sun and glows blue-white. Its diameter is about 70 percent wider and its mass more than double that of the Sun, and its surface temperature reaches over 17,400 F (9,600 C). But unlike our middle-aged, 4.6-billion-year-old Sun, Sirius A is a relative infant, believed to be only 200 million to 300 million years old, which means it formed about the same time the earliest dinosaurs emerged on Earth.

It gets its other name — the Dog Star — from its prime



BELOW: The glare of Siruis A makes its white dwarf companion, Sirius B (lower left), hard to spot, as evident in this image from the Hubble Space Telescope. NASA, ESA, H. BOND (STSCI), AND M. BARSTOW (UNIVERSITY OF LEICESTER)

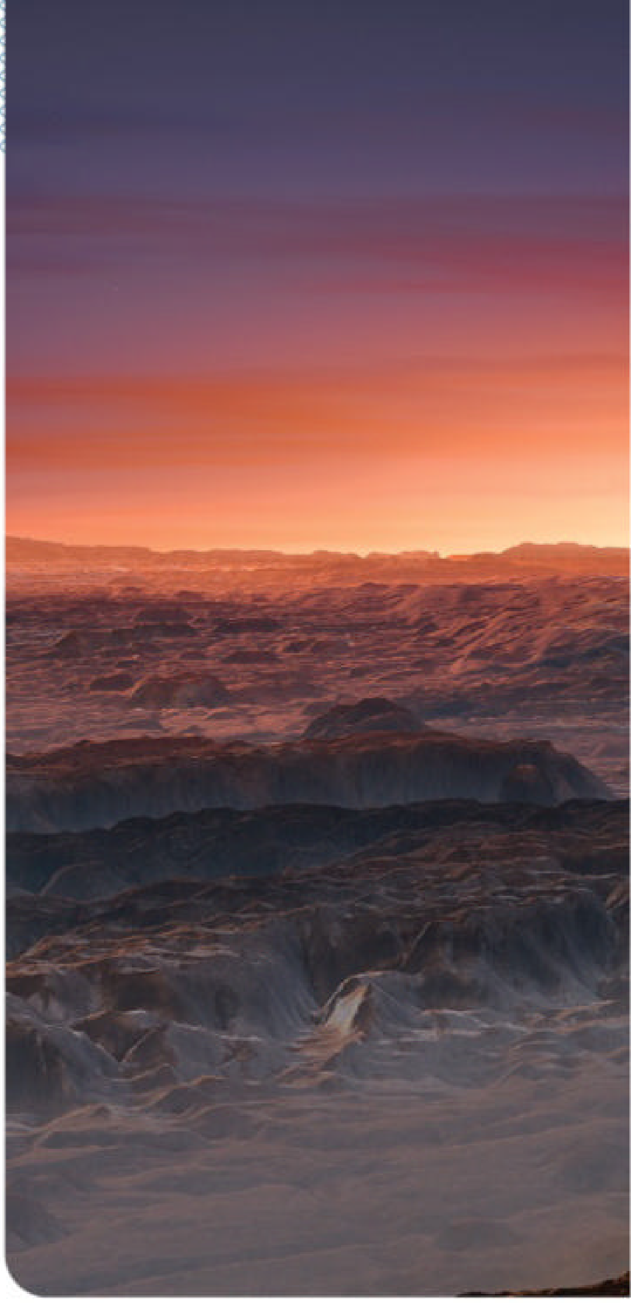


position in the constellation Canis Major (Latin for "greater dog"). The ancient Egyptians called the star Sothis and attributed the annual flooding of the Nile to it, as it appears first in the summer pre-dawn sky in mid-July.

But Sirius A is only half the story. Like Alpha Centauri, Sirius A is gravitationally bound to a stellar companion, Sirius B. They orbit each other 8.6 light-years away with a period of about 50 years. In the mid-19th century, German astronomer Friedrich Wilhelm Bessel inferred from the wobble of Sirius A that it likely had a tiny companion, but it wasn't until after Bessel's death that American astronomer and telescope maker Alvan Graham Clark spied it through a telescope. Sirius B is tiny — about the size of Earth — but its stellar dance with Sirius A suggests it has about the same mass as the Sun. That makes Sirius B a white dwarf, the glowing remnant of a star that's already burned through its hydrogen fuel.

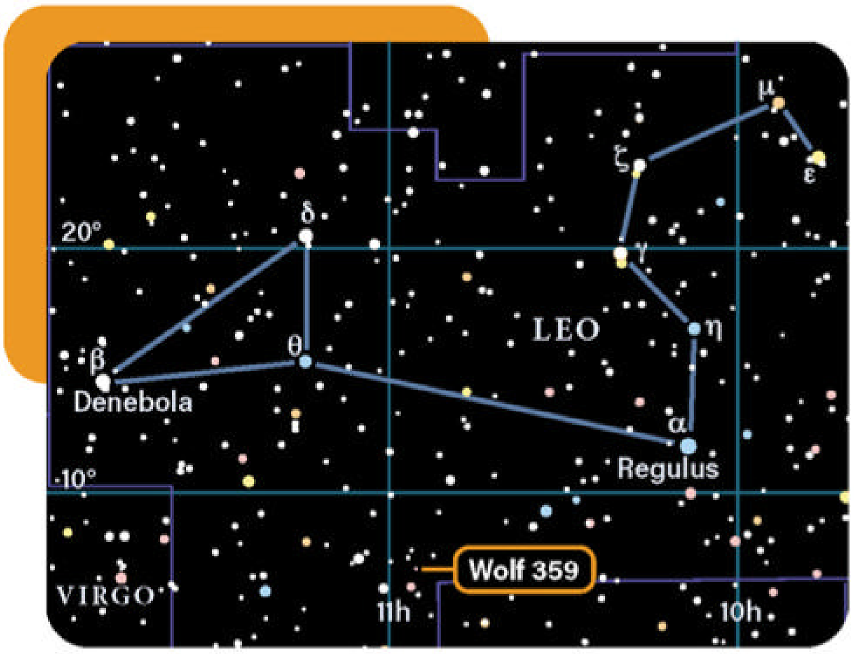
Curiously, in A.D. 140, the philosopher Ptolemy described Sirius as bright red, leading some astronomers to speculate that Sirius B was then a red giant star, outshining Sirius A before it collapsed to its present diminutive state. This seems unlikely, however, based on the timescales of stellar evolution.

No planets have yet been observed around Sirius A or B. Astronomers have flirted with the idea of a low-mass third star in the system since the late 19th century, suggested by apparent orbital irregularities; but recent observations from the Hubble Space Telescope have eliminated that notion.



The red dwarf Proxima Centauri lies just above the horizon of the planet Proxima b in this artist's concept. Though this rocky world lies in its host star's habitable zone, its ability to sustain life is questionable due to the hazardous radiation expelled by Proxima Centauri.

ESO/M. KORNMESSER



Wolf 359 is a small red dwarf star, but it looms large in the cultural imagination.

KLAUS HOHMANN

Meet the Cetis

The last two stars on the list are BL Ceti and UV Ceti, both dim, red, main sequence stars in a binary system roughly 8.6 light-years away within the northern constellation Cetus the Whale. Discovered in the late 1940s when Dutch-American astronomer Willem Luyten was compiling a list of stars with high proper motion, they're also known as Luyten 726–8A and Luyten 728–8B (or collectively as Luyten 726-8 or Gliese 65). They orbit their common center of mass once every 26.5 years at about 5.5 times the Earth-Sun separation, though the distance between them expands and shrinks dramatically over that time because the orbit is so eccentric.

UV Ceti and BL Ceti are physically nearly identical. Each has about one-tenth the mass of the Sun and a radius about 14 percent that of the Sun. Both are flare stars; UV Ceti, which has the more violent temper, was the first known example of this category. Shortly after the star's discovery in 1948, astronomers observed UV Ceti flare to become four magnitudes brighter, its effective temperature soaring to over 10,000 C (17,500 F). After the outburst, the star quickly dimmed.

Today, flare stars are often called UV Ceti variable stars. Over the decades, researchers have observed flares erupting from both stars in Luyten 726-8 in other wavelengths besides visible light, like X-rays and infrared. While stellar variability can arise from many causes, the flares on UV Ceti stars are thought to be the closest analogue to the flares

on our own Sun, driven by the stars' wound-up magnetic fields.

Keeping up appearances

We aren't likely to be able to visit even our closest neighboring star systems anytime soon. But our telescopes have granted us valuable insight into them and their activity.

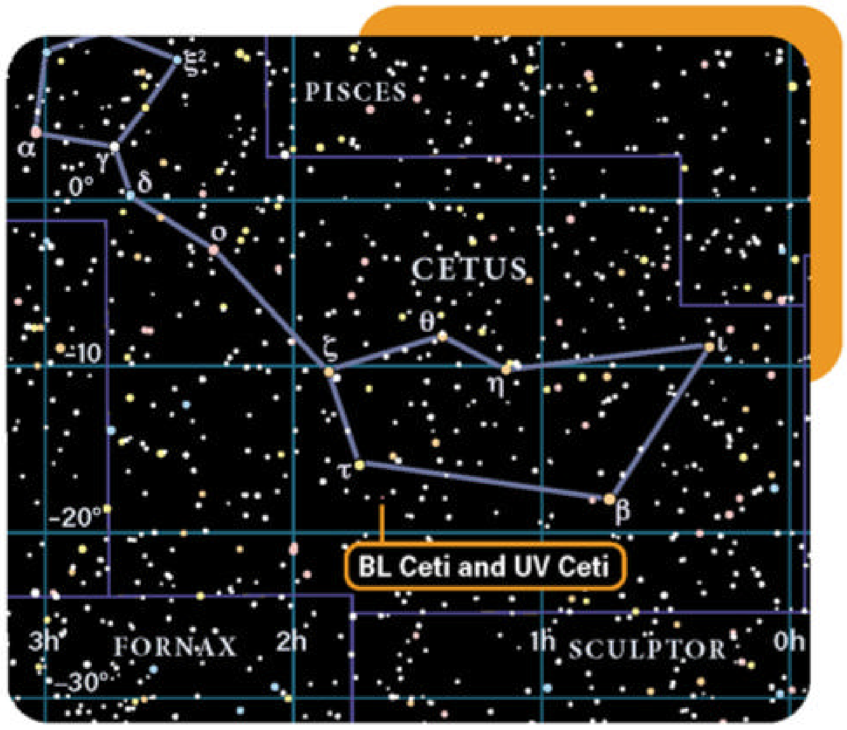
It's also worth pondering how our Sun might appear to any inhabitants of these neighboring systems. With its flares and rich diversity of planets, it would likely be an enticing object for any extraterrestrial astronomers — especially those based around Wolf 359, from which Earth appears to transit the Sun. Among the denizens of this corner of the galaxy, our home star may just be the most fascinating of them all.

Stephen Ornes *is a science writer in Nashville, Tennessee, who covers computer science, math, physics, astronomy, and cancer research.*

WHEN THE CALLS ARE COMING FROM INSIDE THE HOUSE

IN OCTOBER 2022, a team of astronomers published a study in *The Astronomical Journal* that exploited the position of Wolf 359 to search for signals of alien intelligence — coming from our own solar system. They considered the hypothesis (previously proposed) that an advanced alien civilization has colonized the galaxy and placed a network of probes throughout it. If so, these probes could communicate efficiently with neighboring systems by using stars as gravitational lenses to amplify their signals.

By coincidence, Earth appears to transit our star when viewed from Wolf 359, the third nearest system to us. This means that if an alien probe is lurking in the outer depths of our own solar system, we are well-positioned to intercept any possible lensed signals from it sent to Wolf 359. Using a handful of telescopes in Chile, the team scanned for optical transmissions from the region of our solar system where such a probe would be optimally located: behind the Sun, as seen from Wolf 359. Their analysis found no such signal, which could be disappointing — or a relief, depending on your point of view. *— Mark Zastrow*



BLASTS FRO

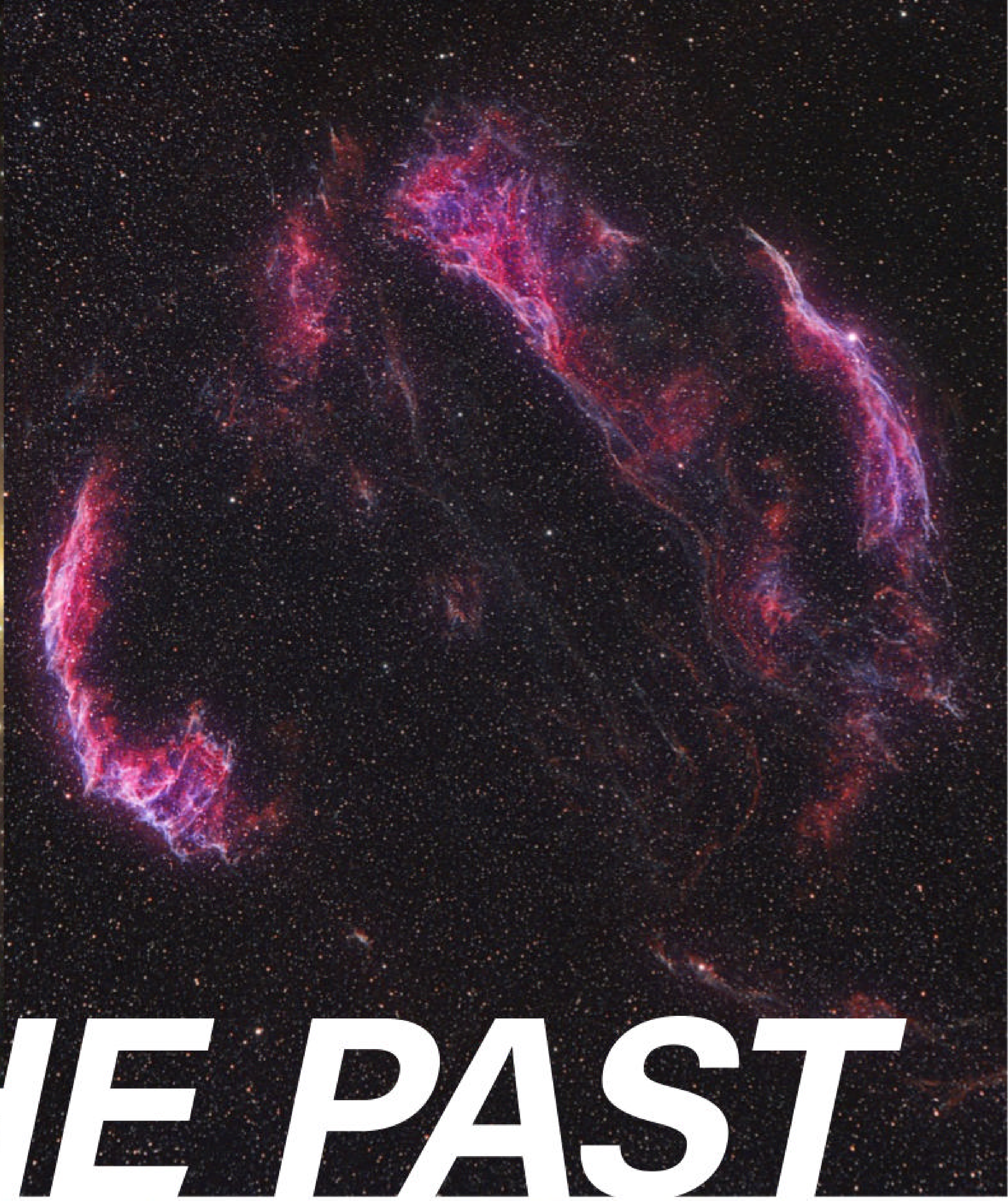
Supernova remnants are colorful tendrils of gas left by exploding stars — and are a worthy challenge to observe.

BY F. MICHAEL WITKOSKI

For as long as humans have been peering upward into the speckled black of night, the sky has exhibited remarkable stability. The seemingly countless stars in our Milky Way obediently hold their places within a moving tapestry that changes only slightly, even over spans of tens of thousands of years or more. Despite minor idiosyncrasies, the Moon and the five naked-eye planets predictably abide by their assigned celestial pathways.

However, roughly every few centuries or so, we get a jolt to this cosmic consistency. It comes from what is perhaps the most unpredictable naked-eye manifestation in our galaxy: the appearance of a supernova, the explosive self-destruction of a star. Rising from obscurity, a blaze graces our skies for several months to a few years before slowly fading away into new and far different avatars. In many cases, a supernova's peak brilliance exceeds that of any nearby nighttime star or planet.

Based on studies of galaxies beyond the Milky Way, astronomers have identified at least two mechanisms producing supernovae in massive stars. One is the cessation of the nuclear reactions that hold up the star. This is quickly followed by its gravitational collapse and the precipitous buildup of its core density and temperature, leading to a rebounding



M THE PAST

↑ LEFT TO RIGHT: The Crab Nebula (M1) is one of the sky's most famous supernovae. Its birth created a new "star" that outshone even the planet Venus. Telescopic views show its tangled filaments, which enclose a rapidly rotating neutron star at its heart. R. JAY GABANY

The Jellyfish Nebula (IC 443) appears snuggled up to the foreground star Eta Geminorum. Scientists believe the remnant's unique shape is caused by density variations in its surroundings. TIM STONE, PAOLO DEMARIA, GIUSEPPE DONATIELLO + DSS2 IR PLATE

The Veil Nebula's two brightest arcs are NGC 6960 (right) and NGC 6992 (left), the Western and Eastern Veil, respectively. The western side, also sometimes called the Witch's Broom, sits near the bright star 52 Cygni. This is a foreground star unassociated with the remnant. MIKE BRADY

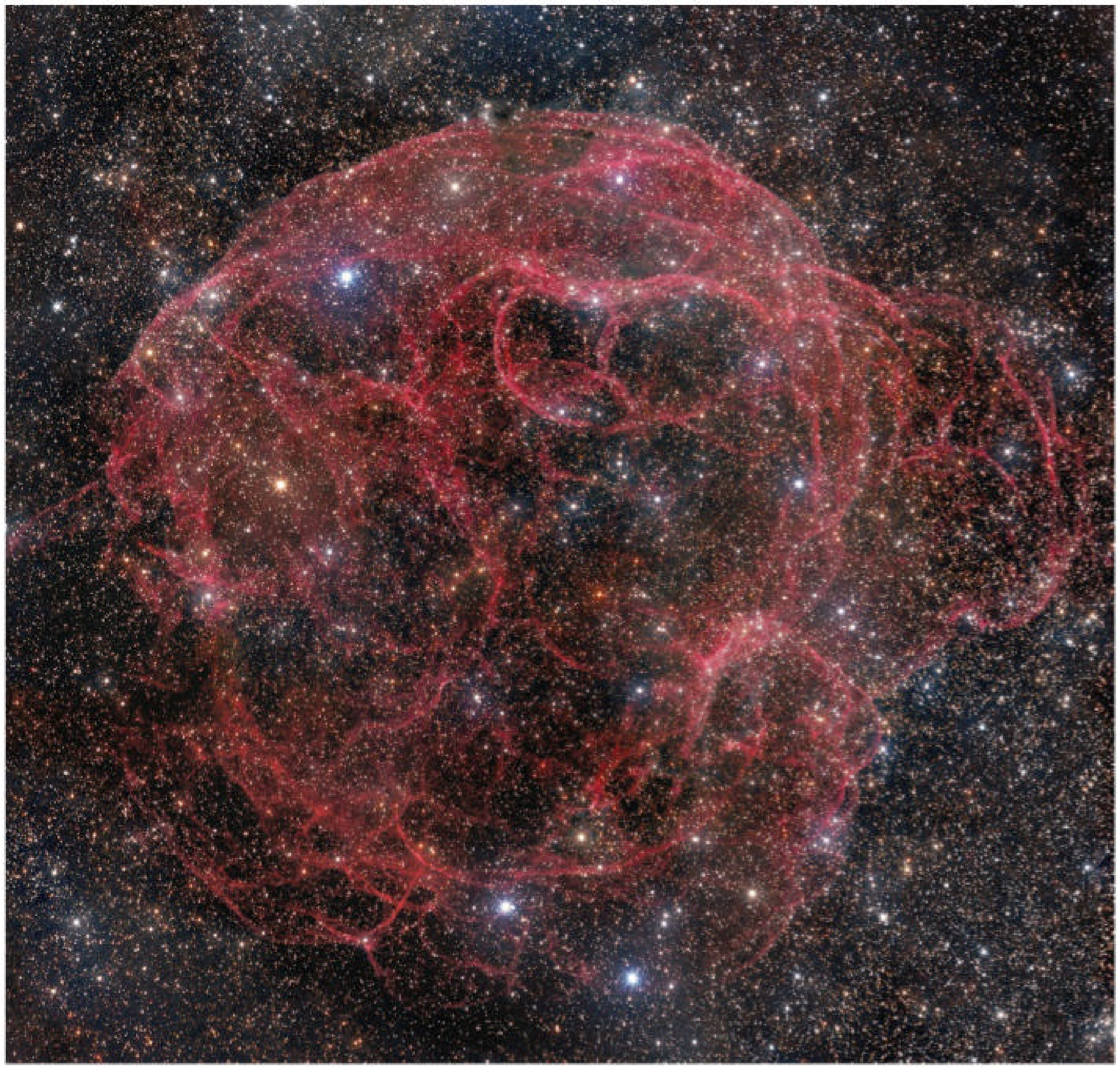
flood of energy. For a short time, the resulting surge of radiation can outshine an entire galaxy, before ultimately fading and leaving behind a neutron star or a black hole. The second trigger is when a white dwarf — the remnant of a Sun-like star that previously shed its outer layers — siphons mass from a nearby companion. If this pushes the white dwarf's mass past a critical destabilizing amount, it results in a thermonuclear blast. Many white dwarfs venturing down this path end up entirely obliterating themselves.

It's hard to understate how powerful supernovae truly are — particularly those that mark stellar deaths, which we'll focus on here. When massive stars explode with such fury, they often leave behind expansive remnants. In sharp contrast to the supernova itself, these leftovers are invisible to the naked eye and often difficult to view, even with a telescope. As the blast site ages, it slowly evolves from a tiny, compact smudge to a larger, more tenuous nebula. And if you have dark skies and decent equipment, there are a few such remnants to seek out.

Peering back

The two most recently observed supernovae within the Milky Way dramatically materialized in A.D. 1572 and 1604, with the latter occurring a mere five years before the telescope was deployed as an astronomical tool. Unfortunately, neither of these stellar explosions bequeathed to us more than dim filaments unobservable with amateur instruments. In recent decades, evidence for additional, similarly difficult-to-observe remnants has surfaced. Either their cosmic fireworks were hidden from our view by star fields or interstellar gas and dust, or their occurrences predated the historical record.

Only two supernova remnants are realistic targets for most amateur telescopes, and they could not be more different. Both inhabit our region of the galaxy. The Crab Nebula (M1) in Taurus the Bull is a small patch approximately 6,500 light-years distant. The Veil Nebula



Also called the Spaghetti Nebula, Simeis 147 sits in Taurus and Auriga. Its surface brightness is so low that it was only discovered photographically.
ADAM BLOCK/STEWARD OBSERVATORY/UNIVERSITY OF ARIZONA

resides between 1,400 and 2,400 light-years away in Cygnus the Swan. It is a widespread system consisting of distinct wisps pushed apart over time, resembling bits of celestial cotton candy.

The Crab Nebula

M1 is the first entry in a catalog compiled in the 1700s by French comet hunter Charles Messier. He intended to help fellow observers separate nebulous objects from their desired cometary quarry. The Crab's telescopically compact mass is the visible aftermath of a supernova first recorded July 4, 1054, by Chinese astronomers; Arabic records of the event also exist. Europeans likely also saw it, but records thereof are nonexistent, have been lost, or possibly were suppressed by Church authorities, whose stance was that the heavens beyond the Moon and planets were immutable. At its brightest, the Crab's supernova progenitor was probably around magnitude –6, brighter than Venus ever appears. The surviving annals tell us that the brilliant blast was discernible in the daytime for nearly a month, and finally faded from nighttime visibility after roughly two years.

Centuries later, in 1731, English astronomer John Bevis discovered the Crab Nebula — though stumbling onto the hazy blur was surely a far cry from witnessing the spectacular event that created it. In 1844, Irish astronomer William Parsons, Third Earl of Rosse, bestowed the Crab its name after noting that its filaments through a 36-inch telescope resembled those of a cosmic crustacean.

The connection between the Crab and the 1054 supernova wasn't clear until the early 20th century, at which point astronomers were only beginning to understand nebulae. In 1942, German-American astronomer Rudolph Minkowski reported that one of two stars at its center had an unusual optical spectrum. He concluded that this star was the driving force of the nebula, whereas the other is merely along our line of sight and not physically associated with the Crab. In 1968, observations of the true central star revealed it spins 30.2 times per second, based on detected pulses that span much of the electromagnetic spectrum. We now know this object is a pulsar, a rapidly spinning neutron star that packs more than a Sun's mass into a sphere roughly 12 miles (19 kilometers) wide.

A small telescope or high-quality binoculars will reveal the Crab Nebula as a somewhat rectangular form with rounded edges and little other detail. With an apparent visual magnitude of 8.4, it measures 6' by 4', making it about one-fifth the diameter of the Moon. Photographically, the Crab emerges as a tangle of tendrils, with more details evident with increasing aperture. To track it down, look about 1° northwest of the 3rd-magnitude star Zeta (ζ) Tauri, which is about 15° northeast of Aldebaran (Alpha [α] Tauri).

The Crab's expansion rate of nearly 1,000 miles (1,600 kilometers) per second corresponds to an annual angular size increase of 0.2". At present, it physically spans some 10 light-years. Photos taken three or four decades apart clearly show the remnant's edges marching outward into the star field, though the advance is too subtle to visually notice over just a few years. As this expansion continues, the Crab will slowly dissolve into oblivion. Astronomers expect that in about 100,000 years — the blink of an eye, cosmically speaking — this captivating remnant will fade into nothingness.

The Veil Nebula

In Cygnus, we find the only other galactic supernova remnant clearly visible through backyard instruments: the Veil Nebula, also known as the Cygnus Loop. This array of nebulosity is sufficiently spread out so that its two most significant portions each merit major designations, NGC 6960 and NGC 6992. These are separated by about 3°, or six Full Moons placed side by side. In some references, NGC 6960 refers to the entire remnant. However, the true NGC 6960 (in the nebula's so-called Western Veil) is not as bright as NGC 6992 (in the Eastern Veil). Spotting the entire Veil requires at least a moderately sized telescope and dark skies. The nebula also includes NGC 6974 and NGC 6979, dim components situated north of its core. And don't forget about NGC 6995 and IC 1340, which extend south of NGC 6992.

NGC 6960 appears to almost touch the 4th-magnitude star 52 Cygni, about

3° south of Epsilon (ε) Cygni. NGC 6992, being brighter than NGC 6960, is visible through good binoculars under ideal conditions. While observing the Veil as a whole, keep in mind that it is best appreciated through a wide-field eyepiece. When imaging, take advantage of the fact that larger amateur instruments will reveal a rich stellar background that nicely contrasts with the nebula's glowing wisps of debris.

Unlike the Crab's creation, which we can precisely pin to 1054, we can only estimate the moment of the Veil's birth. By measuring its present rate of expansion — just under 280 miles (450 km) per second — and adjusting for slowdowns due to interactions with the surrounding interstellar material, astronomers estimate that the supernova that spawned it occurred between 5,000 and 20,000 years ago. Because the Veil is thus much older than the Crab, it has had more time to expand and its midsection has faded, which could at least partially explain the vast visual difference between the two.

Honorable mentions

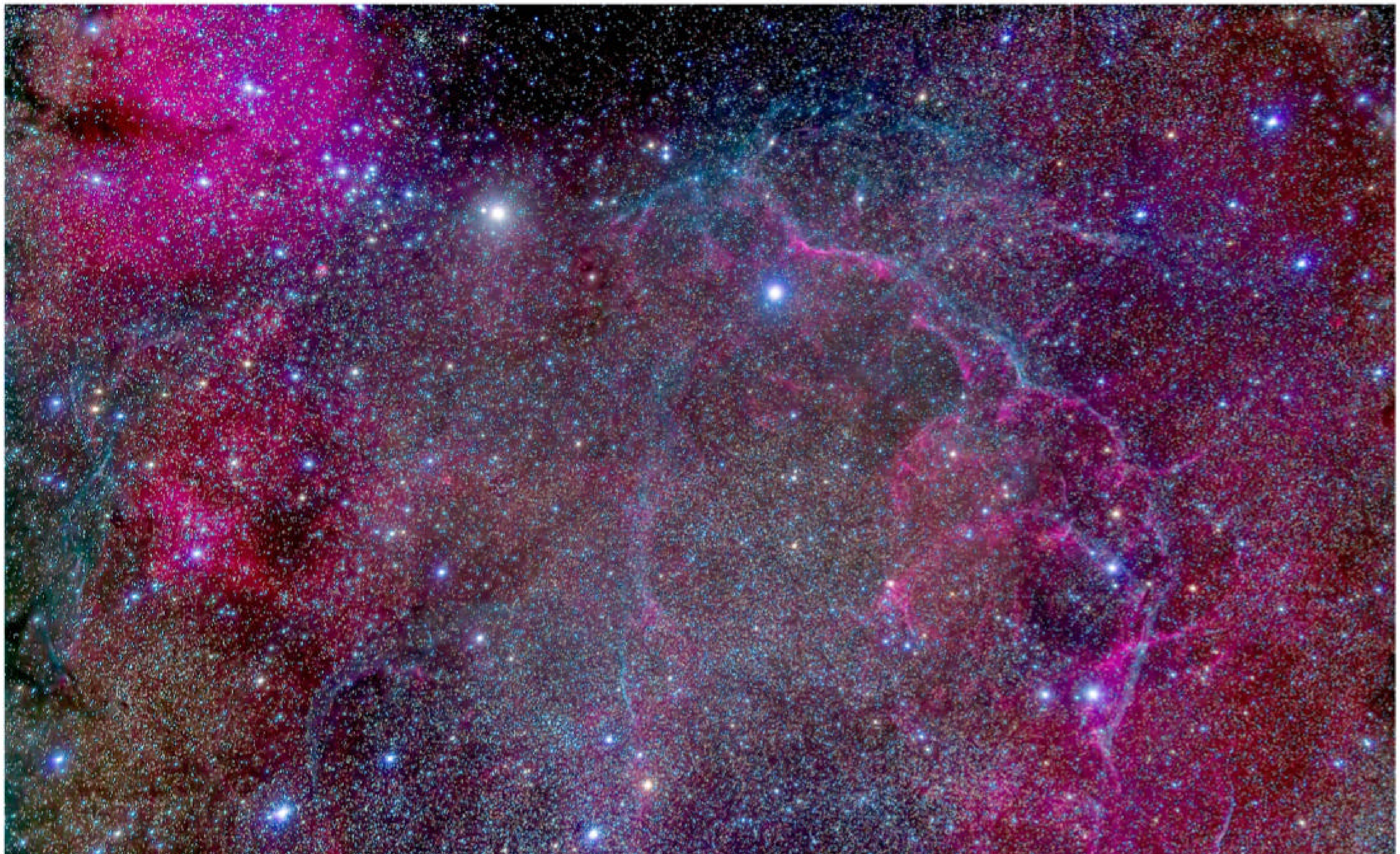
From the Crab and the Veil, we travel to more demanding terrain. Partially in Taurus and spilling over into Auriga is Simeis 147, about 6° north-northeast of the Crab Nebula. This supernova remnant, located roughly 3,000 light-years away, is spread over approximately 3°. Consequently, it has very low surface brightness, making it almost impossible to see with any instrument. Discovered photographically in 1952, it displays filamentary structures that somewhat resemble those of the Veil, though not as spread out or separated. Astronomers estimate the supernova event that created Simeis 147 took place approximately 40,000 to 60,000 years ago, and a rapidly spinning pulsar still resides at its core.

Gemini hosts a supernova remnant designated IC 443. Also commonly referred to as the Jellyfish Nebula, it covers not quite twice the diameter of the Full Moon. Although a challenge to spot, it is observable as a 12th-magnitude tangle about 10° east of the Crab Nebula, between Mu (μ) and Eta (η) Geminorum. The consensus among amateurs seems to be that you'll require at least a 12-inch telescope to spot it and that an O-III filter enhances the view. The Jellyfish, with a poorly known distance between about 3,000 and 5,000 light-years away, is far from uniform thanks to the interstellar medium into which it is expanding, whose density varies with direction.

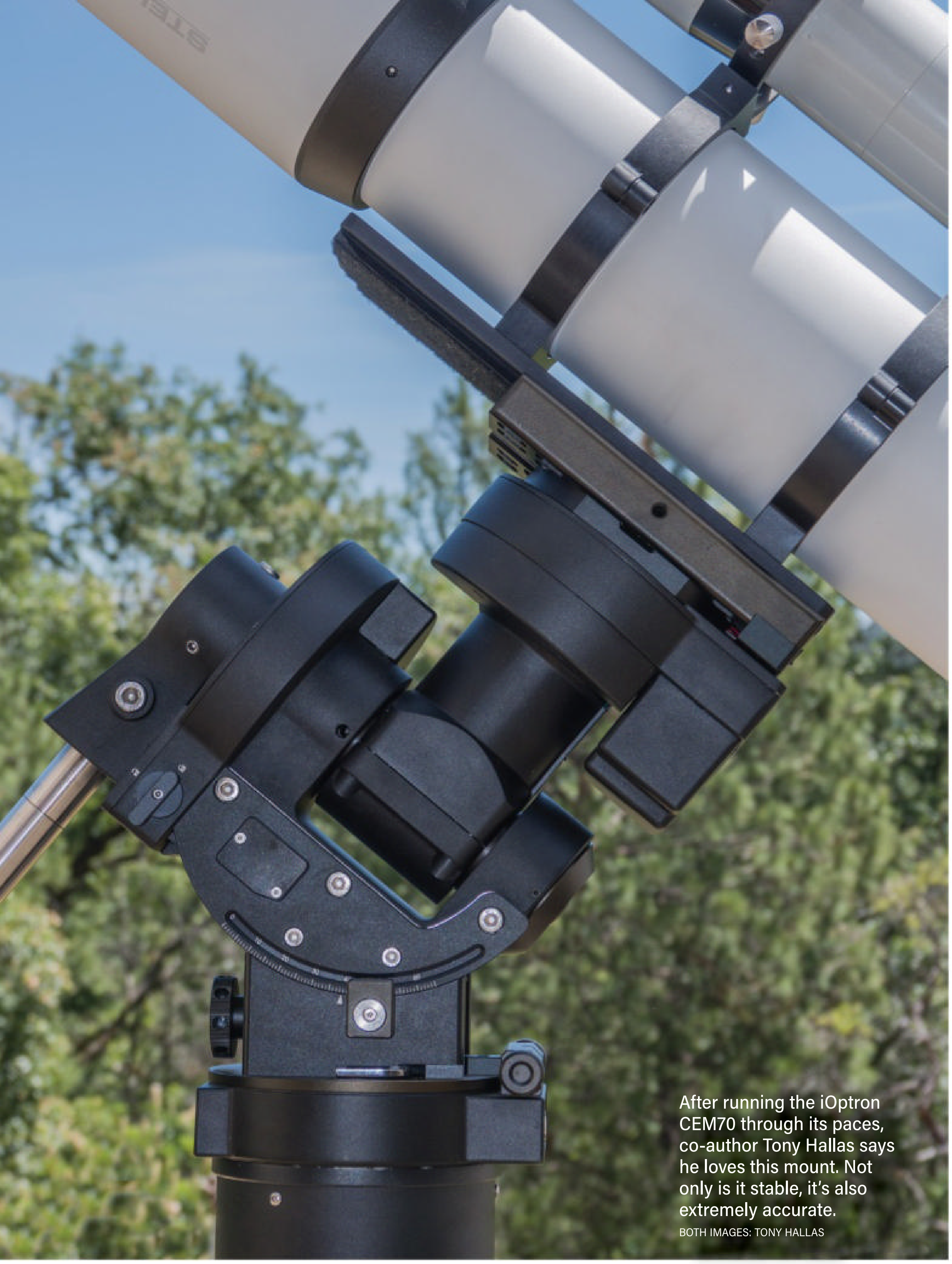
Much closer to Earth is the prosaically named Vela Supernova Remnant in the southern constellation Vela. Some 800 light-years away and visible as a 12th-magnitude spot, the supernova that gave birth to Vela took place approximately 12,000 years ago. Superimposed along our sight line and just 700 light-years distant is another remnant. First identified in 1998, astronomers think this nascent nebula — with the likewise mundane nickname Vela Junior — could be as young as 700 years old.

Despite the current dearth of dramatic (and easily observable) targets, as more sophisticated instruments come online, more supernova remnants are likely to reveal themselves. Although the vast majority will be barely visible, there's always a chance that when the next supernova appears, its resulting remnant will one day give the Crab and the Veil a run for their money.

F. Michael Witkoski *has observed the Crab and Veil through various telescopes. He also volunteers at public events at Muddy Run Observatory in south central Pennsylvania.*



The Vela Supernova Remnant is a mere 800 light-years away. Here, its wispy tendrils appear alongside emission nebulae Gum 17 (upper left) and Gum 18 (left of center). ALAN DYER



After running the iOptron CEM70 through its paces, co-author Tony Hallas says he loves this mount. Not only is it stable, it's also extremely accurate.

BOTH IMAGES: TONY HALLAS

NAVIGATE THE STARS with a new type of mount

With a center-balanced design, iOptron's CEM70 is great for observers and astrophotographers.

BY TONY HALLAS AND FRANK DIBBELL

It's easy to underestimate the importance of a high-quality mount. First-time observers might opt for a cheaper model after splurging on an impressive telescope. But that likely means their mount can't handle the equipment they want to use. Theoretically, visual observers can get away with this, but it's not recommended. And, for an astrophotographer, a high-quality mount with next-level support is crucial.

So, when one of this article's authors, Tony Hallas, was looking for a new portable mount to fit his Stellarvue 140mm f/6.7 refractor setup, he immediately thought of iOptron and their history of solid mounts. In addition to his telescope, the mount had to be able to handle his guide scope and cameras, plus remain stable, track well, and have go-to capabilities. After looking through the catalog, he settled on the iOptron CEM70 mount.

What immediately sets the CEM70 apart from other mounts is its shape: It's a center-balanced equatorial mount. As the name suggests, in this configuration the payload is over the center of the mount. iOptron initially introduced this innovative design with their ZEQ25 model.

With the CEM70, iOptron has built on their initial success by creating a mount that promises added accuracy and efficiency, all in a portable package. Although the mount weighs 30 pounds (13.6 kilograms), it can support a payload over double that at 70 pounds (31.8 kg).

What's in the box

Though the packaging may seem straightforward — a hard case containing the mount head, accessories, and the 21-pound (9.5 kg) counterweight — it's important that you start by consulting the included Quick Start Guide.

Two other guides are also included with your purchase: the standard instruction manual and the iPolar Operation Manual. One more guide may also be in your box, depending on whether you opted for the CEM70-NUC. This mount is for observers who want a ready-to-go connection to any Intel® NUC minicomputer. In this case, the package will also include a NUC connection support document.

But back to the Quick Start Guide.

Anyone who has worked with particularly difficult assembly instructions will be pleased to know that not only is the guide easy to follow, it also includes clearly labeled images. During assembly, it can help to have a second pair of hands to fasten the mount head to a pier or tripod. This is because you can't easily see the spring-loaded bolts nested in the mount plate.

A crucial note: Never disengage the gear switches without first having a firm grip on the mount. Not only could you damage your equipment, but you could also injure yourself.

Once you have your payload balanced, it's time to perform the polar alignment. This is one of the highlights of the mount, in the authors' opinion. Make sure that the iPolar software is installed on your computer and then connect a USB cable to the mount. From there, you can follow the onscreen instructions.

The iPolar program uses a camera to continuously plate solve — compare the star field to a database of star positions — for the location of a bright star, usually Polaris or Sigma Octantis, and the equatorial pole. This lets the system determine exactly where the telescope is pointed without requiring the user to set it for the Northern or Southern Hemisphere, allowing for easy navigation of the night sky.

In the field

Having bought the mount to pair with his Stellarvue 140 setup, Tony found the mount's axes smooth and easy to balance. And, once engaged, the gear locks had no movement at all. If you're running into trouble getting them to lock, Tony suggests rocking them ever so slightly until you hear a clunk.

Using the CEM70, Tony captured this image of the Sharpless 2-132 at the Stellarvue Dark Sky Party at Likely Place, California.

PRODUCT INFORMATION

iOptron CEM70

Type: center-balanced equatorial mount
Mounting plate: Vixen or 8" Losmandy-D
Payload: 70 pounds (31.8 kg)
Slew speed: 1×, 2×, 8×, 16×, 64×, 128×, 256×, 512×; max is 3.75° per second (900x)
Power requirements: 12-volt DC, 5 amps
Weight: 30 pounds (13.6 kg)
Price: $3,228.00
Contact: iOptron
6F Gill Street
Woburn, MA 01801
781.569.0200
support@ioptron.com

While there is the option to run the mount using the iOptron Commander software on your computer, Tony preferred the hand paddle because he considers it well laid out and very powerful. As an added bonus, the paddle is heated.

If you do opt to use the Commander software, co-author Frank Dibbell found that the program seamlessly integrates with various imaging automation packages. The software has more than 200,000 objects stored in its memory.

Tony found that, once aligned to just one reference star, the mount centered every object in the eyepiece, from the Orion Nebula (M42) all the way over to the Cigar Galaxy (M82). Thus, the CEM70 is great for all-sky tours.

One potential problem does plague the mount, but iOptron provides a solution. After extended use, the CEM70 can start to drift in either right ascension or declination, even with the locks engaged. If this starts to happen, you can adjust the CEM70 gear yourself, as outlined in the instruction manual.

Overall, however, each of the authors found little to complain about the mount, and much to praise. Tony was especially impressed with the usability of the polar alignment in the field.

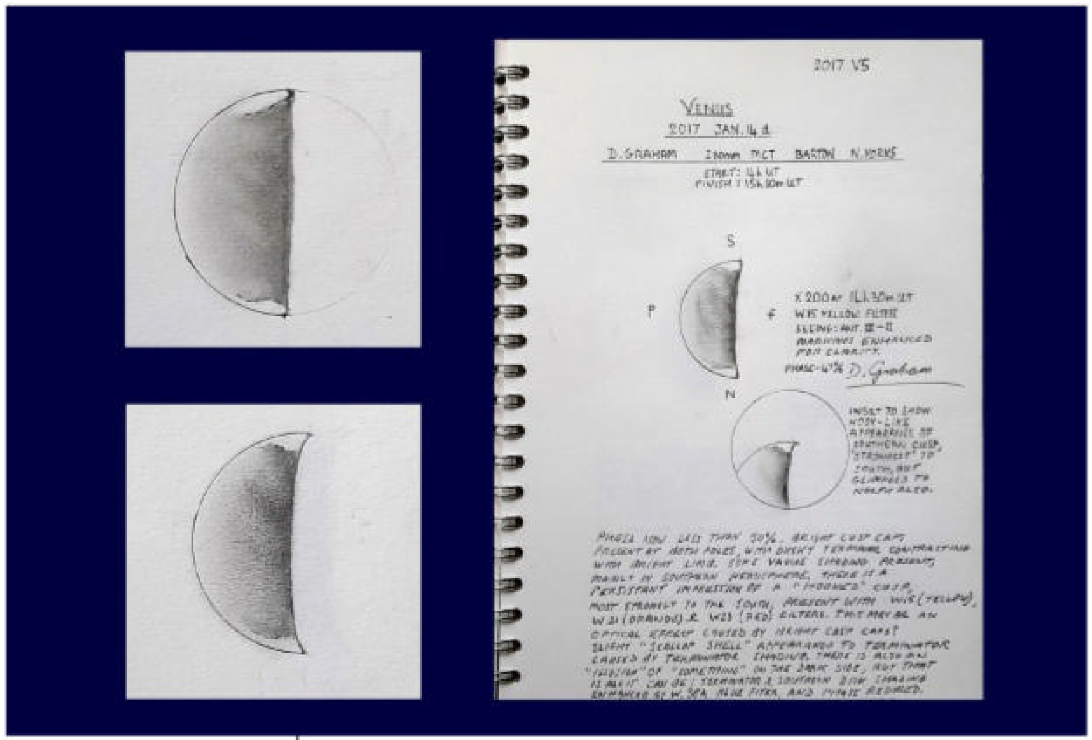
In addition to the remarkable tracking, Tony found that with his 140mm refractor, the mount was more than capable of handling a moderate wind. He looks forward to many nights of viewing and imaging with this modern mount.

Because the CEM70 doesn't come with a pier or tripod, buyers have the option of adding a LiteRoc tripod to their purchase. Instead, the authors suggest opting for the Tri-Pier. Although it is almost double the price — the LiteRoc is $360 and the Tri-Pier $698 — the Tri-Pier is lightweight, sturdy, and capable of handling more than 200 pounds (90 kg).

Tony Hallas *and* **Frank Dibbell** *are considered two of the world's top astroimagers.*

A Venus challenge

Careful observations can reveal fascinating features.



David Graham made these drawings of Venus in daylight, as seen through his 9-inch Maksutov-Cassegrain telescope. The planet was near half-phase during a favorable apparition in January 2017. At left is his observation at 250x on Jan. 5 (top) and at 155x on Jan. 22 (bottom). At right is an observation taken from his journal at 200x on Jan. 14. Note the bright polar cusps with scalloping. DAVID GRAHAM

Venus, the brightest planet — and paradoxically one of the greatest visual challenges through any telescope — reaches greatest eastern elongation June 4 at 16h11m UT, 13 hours after the planet achieves dichotomy (half-phase). If you're up for a telescopic adventure that will test your visual mettle, now is a great time to search for elusive cloud features on our sister world.

The surface of Venus is blanketed by an impenetrable cloud layer of sulfuric acid and aerosols. Although the planet looks featureless to the casual viewer, it is tantalizing to the skilled observer. Ever since Giovanni Domenico Cassini, the first director of the Paris Observatory, noticed bright and dark spots on Venus in 1666 and 1667, patient observers have spied a variety of subtle details in this most enigmatic of atmospheres.

Take Denning's advice: Observe in daytime, or near sunrise or sunset.

Venusian cloud features are most apparent around greatest elongation, when the planet appears farthest from the Sun in our sky and can be studied in daylight. In his 1891 volume *Telescopic Work for Starlight Evenings*, British amateur astronomer William Frederick Denning asserted that "the lustre of Venus is so strong at night that her disk is rarely defined with satisfactory clearness." If you want to maximize your chances of success, take Denning's advice: Observe in daytime, or near sunrise or sunset.

The cloud features commonly seen on Venus can be grouped into three categories by latitude: bright polar cusps, sometimes bordered by a dark collar; fingerlike shadings projecting from the terminator; and bright and dark spots, including mottling.

These features, seen throughout the ages by capable observers, are supported by modern spacecraft observations. The Venus Monitoring Camera on the ESA's Venus Express has found that (1) at high latitudes, the cloud structure appears as a dense, almost featureless haze forming a kind of polar cap, sometimes with dark streaks; (2) at mid-latitudes, clouds appear streaky; and (3) near the equator, the shapes are spotty and fragmented. The data also suggest a global north-south symmetry of the overall cloud top structures.

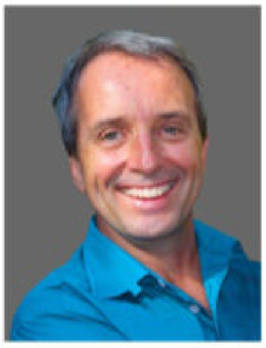
According to Richard McKim of the British Astronomical Association (BAA), a study of observer reports from 1999 to 2009 showed that ultraviolet images of Venus "agree well with the best visual drawings, and especially with those made in blue or violet light, so there is no doubt that quality visual data are still highly valuable."

The planet's bright cusp caps, which can be seen through instruments as small as 2.4 inches, often appear with a dusky terminator that can show deformation, according to BAA planetary observer and artist David Graham of Barton, North Yorkshire. The latter is an optical effect caused by bright or dark shading being present next to it. Graham, who uses a 9-inch Maksutov-Cassegrain telescope, says all his observations are made in broad daylight, usually with Baader filters (blue, yellow, orange, and red). The blue filter especially allows cloud features to be enhanced, he says.

Features in the clouds of Venus may give us a glimpse of activity deep inside the planet. In the winter 2009 issue of *The Strolling Astronomer*, Michael F. Mattei reported 21 bright terminator bulges that appeared in archival data. Using software to plot the locations, Mattei found that in all 21 cases, the bulges were at or near the locations of three volcanic structures on Venus: Maat Mons, Ozza Mons, and Sapas Mons.

Are these volcanoes on Venus currently erupting? In 2015, researchers reported in *Geophysical Research Letters* that Venus Express recorded a series of hotspots at several locations, fading within days. These observations "make a strong case" that Venus is volcanically active today, geologist James Head of Brown University noted in a news release at the time.

So take this opportunity to study Venus like you've never studied it before. Who knows what you'll discover? As always, send your thoughts/observations to sjomeara31@gmail.com.



BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.

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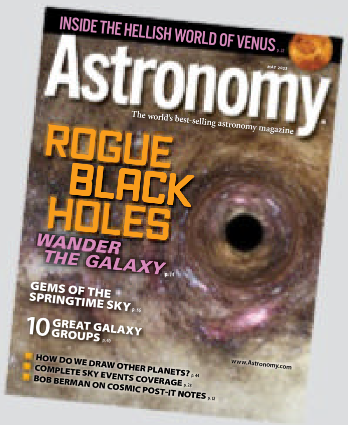

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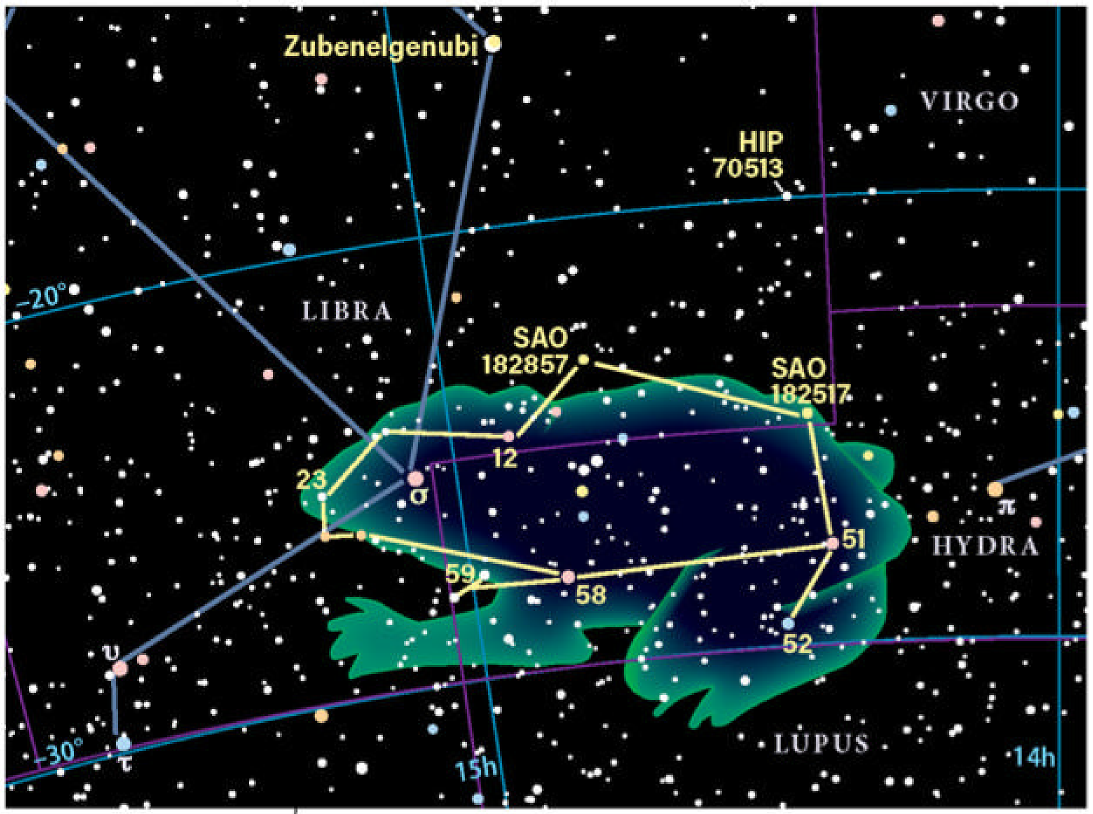

Bufo the Toad is one of hundreds of unapproved constellations, but offers a playful viewing challenge.

ASTRONOMY: ROEN KELLY

BY PHIL HARRINGTON

Phil received the Walter Scott Houston Award at Stellafane 2018 for his lifelong work promoting and teaching astronomy.

Today, we recognize that the sky is divided into 88 standard constellations with well-defined boundaries, as adopted by the International Astronomical Union. You might be surprised to learn, however, that these were only officially approved 101 years ago. Before 1922, astronomers and authors could create their own constellations using fainter stars scattered among the more easily recognizable figures. There were constellations portraying historic figures, instruments, and all sorts of living creatures. Most have faded away over time, but a few are still worth remembering.

In the 1980s, several members of the Skyscrapers, Inc. astronomy club in Rhode Island wanted to do something about that. They decided to start a tongue-in-cheek campaign called "Bring Back Bufo" to call attention to one of these long-gone constellations.

Bufo the Toad was concocted by eccentric English scientist, actor, and author John Hill. In 1754, Hill published a dictionary of astronomical terms entitled *Urania: Or, a Compleat View of the Heavens*. In the book, he proposed filling the empty spaces between several constellations with smaller, unsung creatures. In all, he dreamt up 15 constellations. Besides Bufo, there were Anguilla the Eel, Hirudo the Leech, Limax the Slug, and Scarabaeus the Rhinoceros Beetle, among others. A follow-on edition published in 1768, entitled *A New Astronomical Dictionary*, included illustrations of all these.

Bufo lies within a barren portion of the southern sky, bridging Libra the Scales and Hydra the Water Snake. Both Libra and Hydra can be difficult to find under less-than-ideal skies.

Binoculars are needed to trace Bufo's form, which spans nearly 10°. It's best to start at Libra's brightest star, the 3rd-magnitude tongue twister **Zubenelgenubi** (Alpha^2 [α^2] Librae), located 21° east-southeast of Spica (Alpha Virginis). From there, scan southward to **Sigma (σ) Librae**. At 3rd magnitude, Sigma marks Bufo's eye and is the Toad's brightest star. Sigma is a red giant star lying 288 light-years away, and is over 100 times larger and 1,800 times brighter than our Sun.

East of Sigma lies **23 Librae**, the tip of Bufo's nose. From here, retrace your steps west and move on to 5th-magnitude **12 Librae**, then along to the slightly fainter stars **SAO 182857** and **SAO 182517**.

From there, the Toad hops into Hydra, where 5th-magnitude **51 Hydrae** marks its hip. Bufo looks like it's ready to leap, with its hind leg stretching southeastward to **52 Hydrae**.

Meanwhile, the toad's belly extends northeast to **58 Hydrae**. Look just to the north for five 5th-magnitude stars set in an arc-shaped asterism that I call Bufo's Bicep.

Completing the toad, the front leg extends to **59 Hydrae**, while the rest of its body is connected back to 23 Librae.

Once you figure out Bufo, locate two nearby double stars within Libra. I like to think of them as two flies tempting our toad to jump northward. The closer target of the two is **HIP 70513**, found by James South and John Herschel. The stars shine at magnitudes 6.6 and 7.0 and are separated by about 35". That makes them bright enough and wide enough to split through 10x binoculars, especially if those binoculars are mounted on a support. Both are pure white, type A stars, although some observers have noted they appear yellowish.

> **There were constellations portraying historic figures, instruments, and all sorts of living creatures.**

A second double lies farther north. In fact, we already stopped by it briefly on our way to Bufo. Zubenelgenubi is composed of a 3rd-magnitude primary and a 5th-magnitude secondary separated by 231". Those values mean that Zubenelgenubi is easy to resolve even through 8x25 pocket binoculars.

Bufo may never have achieved fame and glory like some other constellations, but viewing it is a fun way to keep its memory alive for a new generation.

Comments or suggestions? Contact me through my website, philharrington.net. Until next time, remember that two eyes are better than one.

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Settling on Mars

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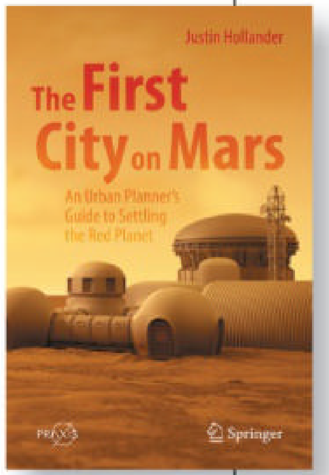

Ever wondered what a neighborhood would look like on Mars? In *The First City on Mars: An Urban Planner's Guide to Settling the Red Planet,* Justin Hollander, an urban development professor at Tufts University, lays out a residential and commercial plan for our planetary neighbor. From transportation to high rises, Hollander details what city building on Mars will require, with blueprints and illustrations included.

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Adventures in Astronomy 5
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Archaeological Paths 2
Armstrong Metalcrafts 5
Bob's Knobs 53
Celestron 60
Charles Fulco 53
Chiracahua Sky Village LLC 53
Daniel R Spirer Jewelers, LLC 51
Dream Telescopes 51
Eclipse Traveler 6
iOptron 51
Lowell Observatory 5
Metamorphosis Jewelry Design 5
NEAF DEALER PAGE 60
Oberwerk 51
Precise Parts 53
Rainbow Symphony 53
Scope Buggy 5
Space and Beyond Box 59
Technical Innovations 53

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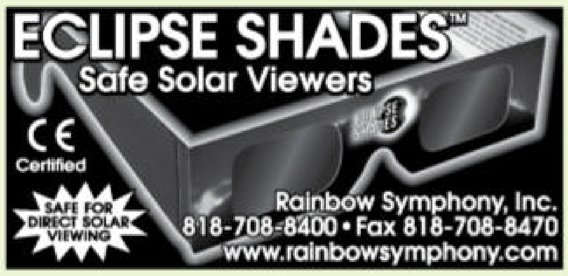
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Hydrogen-alpha filters show the Sun at a wavelength of 656.28 nanometers, in the red portion of the visible spectrum. However, the corona does not appear in images taken at this wavelength. PAUL STEWART

Imaging the Sun

Q I'VE NEVER SEEN ANY ECLIPSE PHOTOS USING A HYDROGEN-ALPHA ($H\alpha$) FILTER. IS THERE ANY REASON NOT TO USE SUCH A FILTER FOR TAKING PHOTOGRAPHS OF A TOTAL SOLAR ECLIPSE?

Stephen Nelson
Evergreen, Colorado

A The reason involves how astroimagers targeting a total solar eclipse want to allocate their time. In short, you can take an $H\alpha$ shot of the Sun on any day.

A shot during the partial phases of an eclipse will show whatever percentage of the Sun is visible, albeit in $H\alpha$. During totality, the Moon blocks the Sun's disk, so the filter will only show the prominences at its edge.

Astronomers (professional and amateur) know the main reason to photograph totality is to reveal the spectacular solar corona, the outer atmosphere of our daytime star. Unfortunately, it will not show up in an $H\alpha$ image, so few people have taken such photos during total solar eclipses.

Michael E. Bakich
Contributing Editor

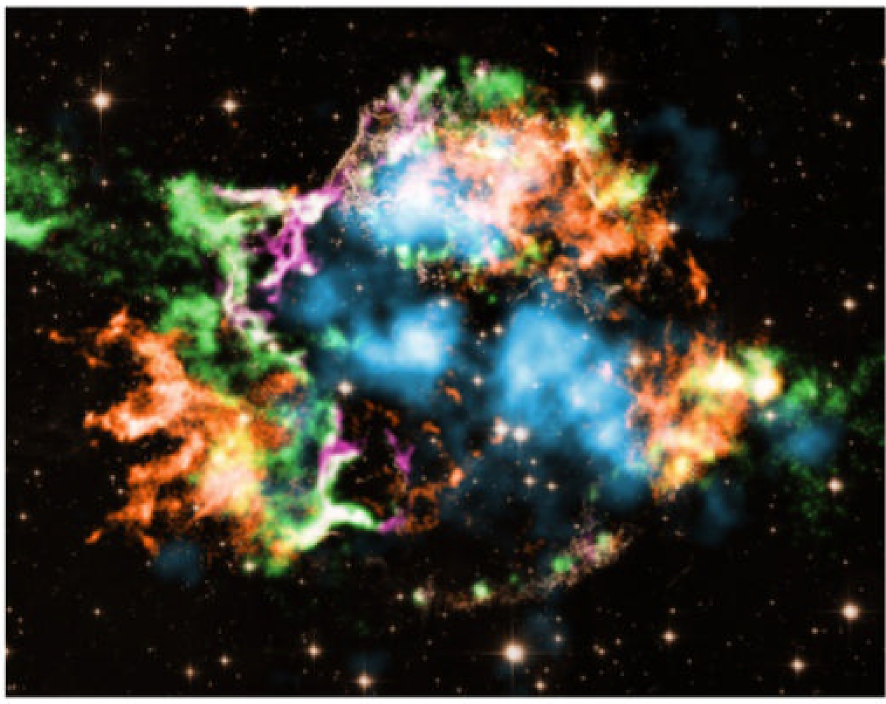
Q WHEN STARS GO SUPERNOVA, DO THEY ALL PRODUCE THE SAME HEAVY ELEMENTS? HOW DO THE PERCENTAGES COMPARE FOR THESE ELEMENTS IN EACH STAR?

Dale Miller
Springfield, Ohio

A Isn't it amazing that the heavy elements we see here on Earth were created by stars going supernova? The short answer to your question is that different kinds of supernovae are caused by different kinds of stars. Depending on their mass and type, these stars disperse different elements into the universe.

To look a bit deeper into the answer, let's examine the different types of supernovae. Broadly, there are two: those with relatively little hydrogen in their explosions (type I), and those with a lot of hydrogen (type II). Of the type I supernovae, there are three sub-types: Ia, Ib, and Ic.

Type Ia supernovae are caused by the thermal



Cassiopeia A was a type II supernova. This composite image shows, in different colors, several elements detected within the remnant: iron (orange), oxygen (purple), titanium (light blue), and the amount of silicon compared to magnesium (green). Background stars and galaxies appear in yellow. CHANDRA: NASA/CXC/RIKEN/T. SATO ET AL.; NUSTAR: NASA/NUSTAR; HUBBLE: NASA/STSCI runaway process. This happens when a star with roughly the mass of the Sun dies and leaves behind a white dwarf star rich in carbon and oxygen. If it is in a binary system, the white dwarf will start stealing gas and dust from its companion and heat up. Eventually, the white dwarf will heat up so much that carbon fusion is ignited, and it goes supernova. Type Ia supernovae populate the surrounding environment with lots of carbon, as well as silicon, nickel, and elements up to iron.

Types Ib and Ic and type II supernovae are caused by the core-collapse process that happens when stars with masses greater than eight times the mass of the Sun end their lives. Generally, very massive stars (around 30 times that of the Sun) create the hydrogen-poor type Ib/Ic supernovae, while stars between eight and 30 times the mass of the Sun create the hydrogen-rich type II supernovae.

While core-collapse supernovae also populate the surrounding environment with elements up to iron, they generally do so in much lower quantities compared with type Ia supernovae. Instead, they primarily eject elements heavier than zinc and are one of the main sources in the universe for creating these elements.

Kathryn Neugent
NASA Hubble Postdoctoral Fellow, Harvard University, Cambridge, Massachusetts

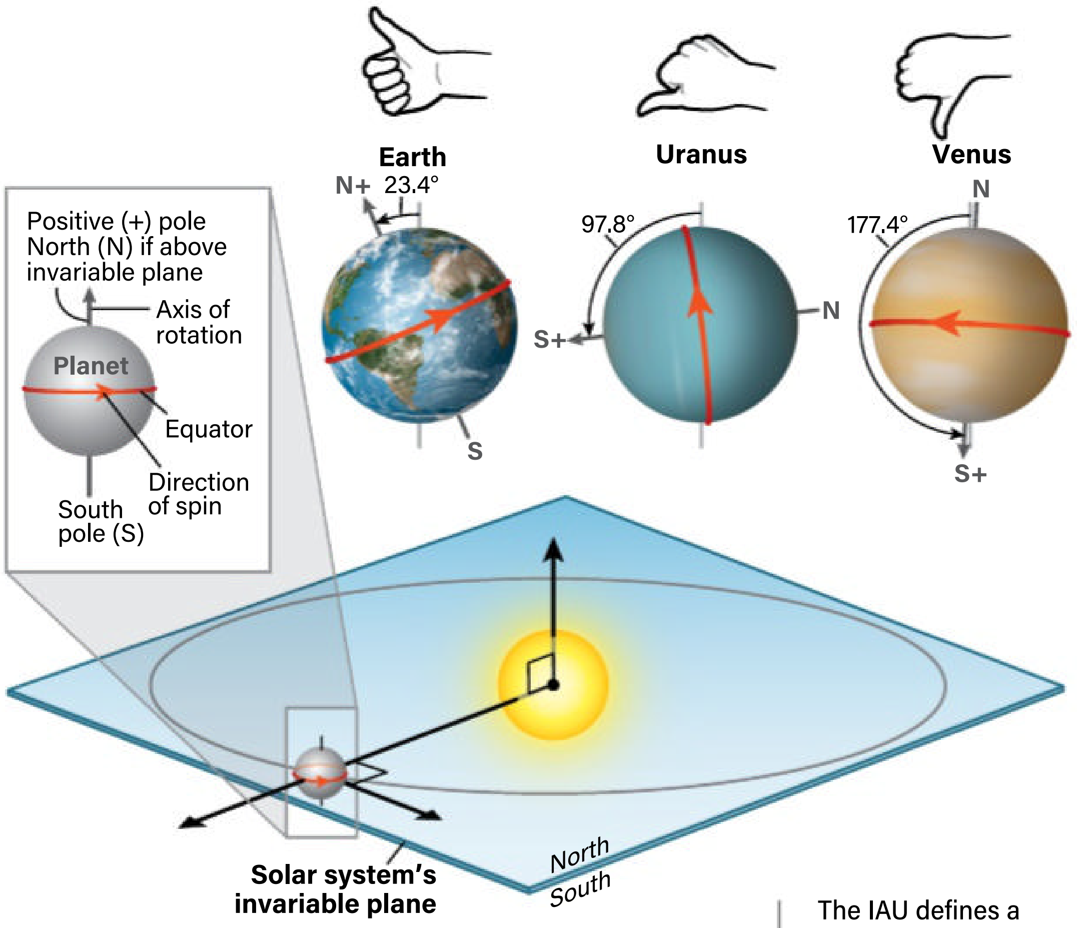
Q | HOW DO WE DISTINGUISH THE NORTH POLE FROM THE SOUTH POLE OF PLANETS OTHER THAN EARTH? IS IT AN ARBITRARY SELECTION, OR IS THERE A MAGNETIC FIELD DIRECTION WE RELY ON?

Gary George
Cincinnati, Ohio

A | According to the International Astronomical Union (IAU), a planet's north pole with respect to its rotation is the pole on the north side of the invariable plane of the solar system. This plane is perpendicular to the angular momentum vector of the solar system and also passes through its barycenter (its center of mass).

Angular momentum is related to rotational motion. As an object spins, its angular momentum vector points along its axis of rotation, as defined by the right-hand rule. This rule states that if you hold out your right hand and curl your fingers in the direction of rotation, your thumb points along the axis of rotation. The solar system's angular momentum consists of the contributions of the Sun and all the planets, asteroids, comets, etc., orbiting it. From this, you can calculate the solar system's axis of rotation. The invariable plane, then, is perpendicular to this axis and passes through the barycenter — the center of mass of the solar system.

PLANETARY POLES



The IAU defines a planet's north pole as the pole lying north of the solar system's invariable plane. A planet's positive pole is determined using its direction of rotation and the right-hand rule: When you curl the fingers of your right hand in the direction of rotation, your thumb points toward the positive pole. The positive and north poles may not be the same. *ASTRONOMY*: ROEN KELLY

The invariable plane is not exactly the ecliptic, which is defined as the plane of Earth's orbit around the Sun, though it's close, inclined by less than 2°. But while the ecliptic can change over time, the invariable plane is, well, *invariable*, so it provides a naturally fixed reference point. And whichever pole of a given planet is above our solar system's invariable plane is the north rotational pole — regardless of the direction of that planet's magnetic field (provided it has one) or its rotation.

Most planets rotate in the direction of their motion around the Sun. But, for instance, Venus rotates retrograde — backward compared to the direction of its orbital motion. Based on the IAU's definition, Venus' north pole is still the one north of the solar system's plane, just like the prograde planets'.

Then why does NASA list the tilt of Venus and Uranus as 177.4° and 97.8°, respectively? There is another way to define a planet's poles, using the same right-hand rule. Using your right hand, curl your fingers in the direction of the planet's rotation. Your thumb is pointing in the direction of the *positive* pole, so called to avoid confusion with north pole. For six of the eight planets in our solar system, the positive pole lies above the ecliptic, so these planets' tilts are less than 90°. But for Venus and Uranus, curling your fingers in the direction of their rotation (which appears backward from above their IAU-defined north poles) would cause your thumb to point downward; their positive poles are thus tilted by 177.4° and 97.8°.

Alison Klesman
Senior Editor

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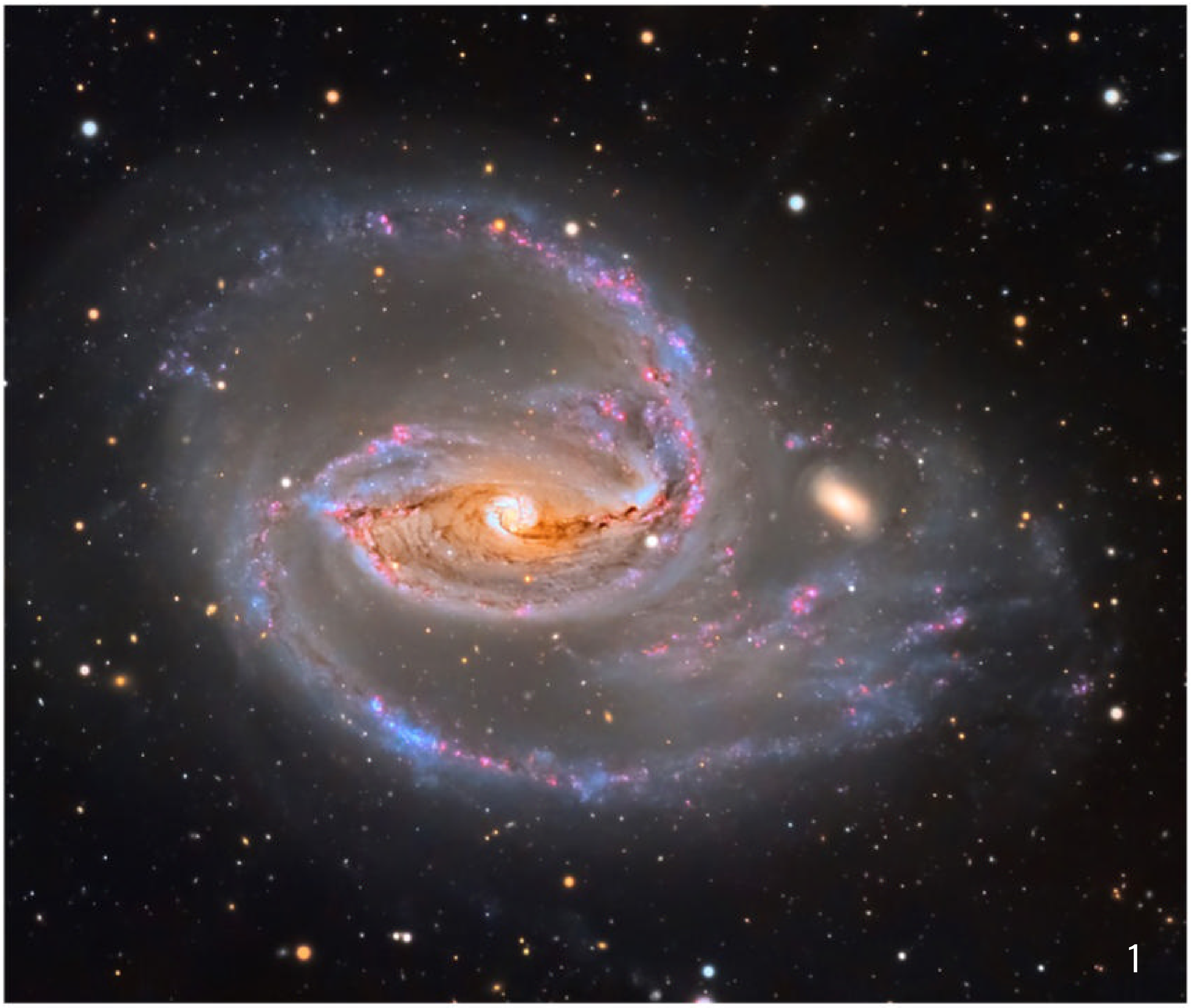
Cosmic portraits

1. EYE OF THE STORM
At the core of the spectacular barred spiral NGC 1097 in Fornax lies a right star-forming ring that surrounds its supermassive black hole, leading the collaboration of 12 astroimagers who pooled funds to obtain this image to dub it "The Eye of Horus." The HαLRGB data for this shot were captured over 7.3 hours with a 1-meter telescope via the remote-observing service Chilescope. The image at right is this imager's own interpretation of the data.
• Massimo Di Fusco

2. ROSEBUDS
The fine detail of Bok globules — dark, dense clouds that will form stars — is on display in this closeup of the venerable Rosette Nebula (NGC 2237–9/46) in Monoceros. The image represents 31.7 hours of exposure with a 12-inch scope captured in the Hubble palette.
• Ioan Popa

3. ENEMY OF MY ANALEMMI
When photographed every day at the same local time, the Sun's annual motion traces the figure-eight shape of an analemma in the sky. For this image, the photographer combined a panorama of the Arcatelle Aqueduct in Italy with three sets of solar images taken in the morning, at solar noon, and in the afternoon.
• Marco Meniero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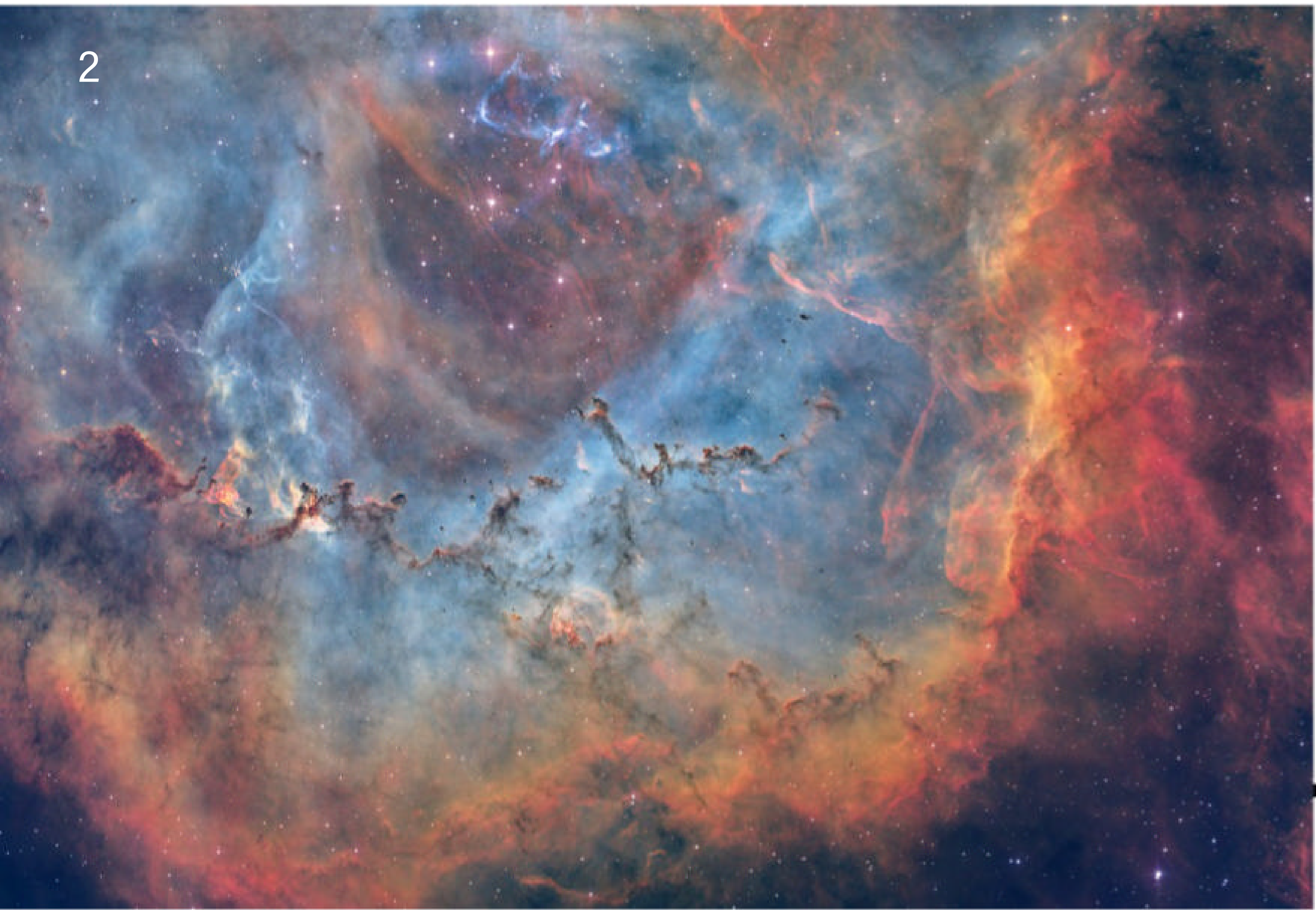
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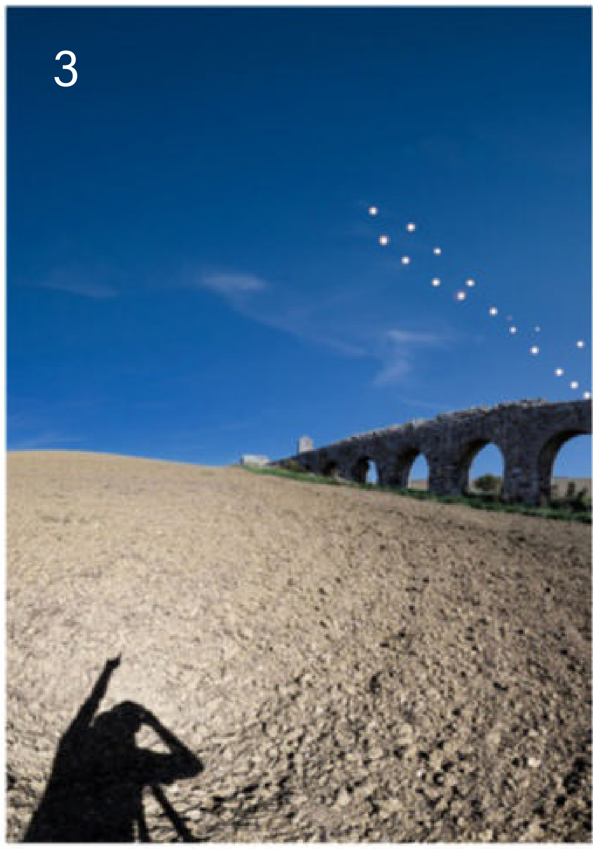
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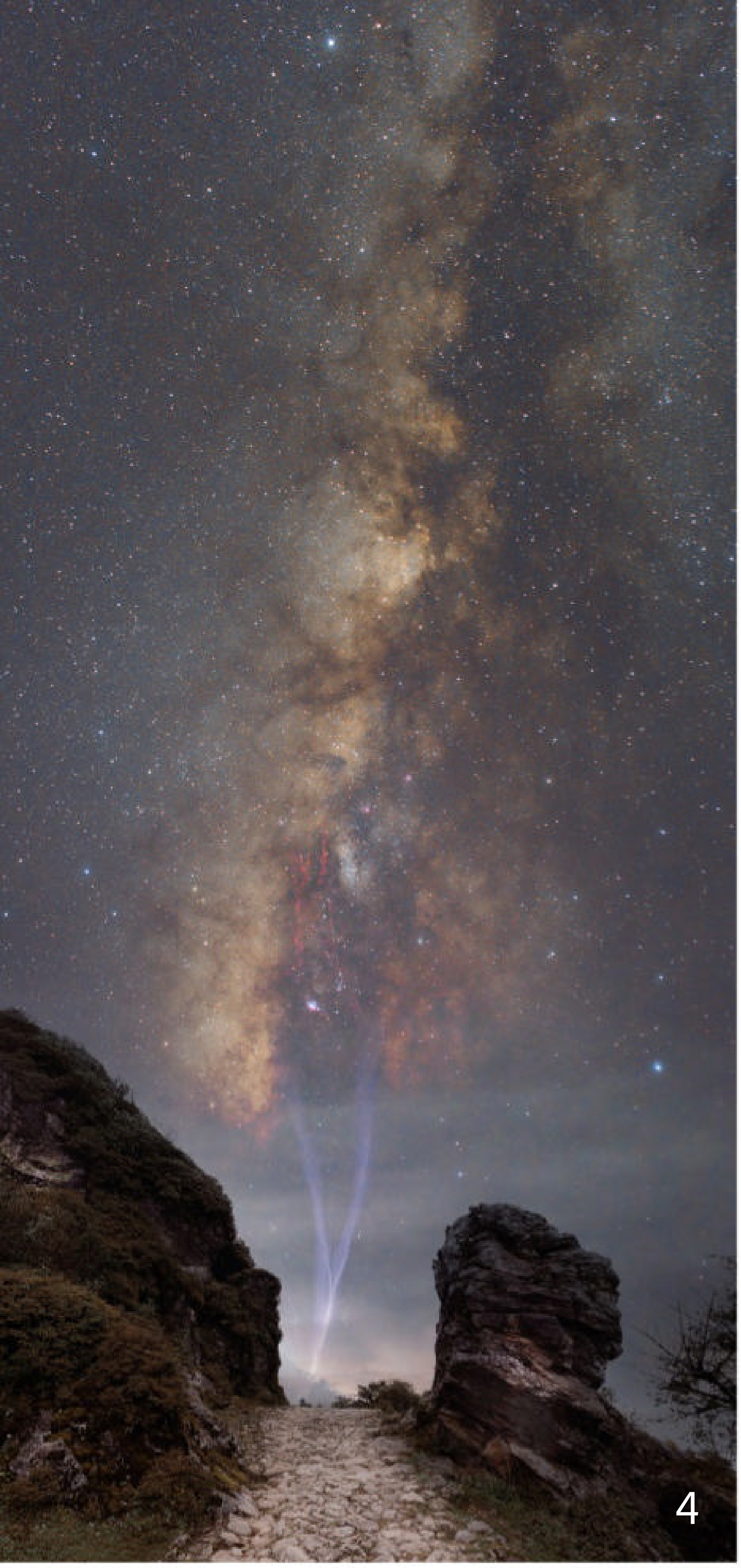

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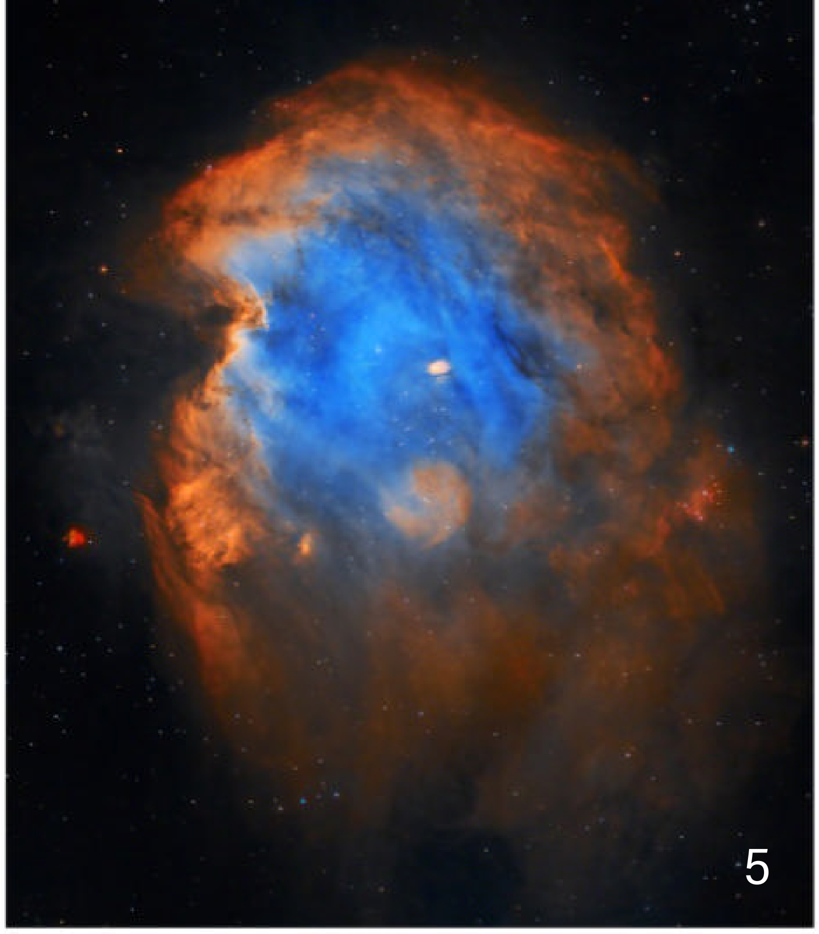

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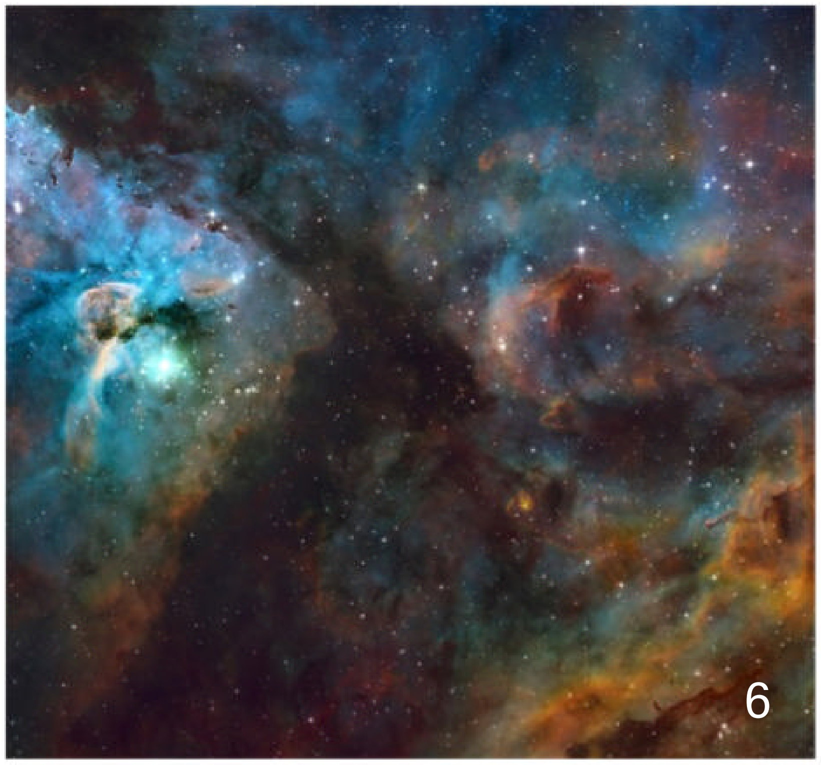


6

4. NOT THAT KIND OF JET

The blue jet captured in this image is not emerging from the Milky Way's core — rather, it's a type of lightning in the upper atmosphere. This type is most easily observed from space and rare to catch from the ground. Also faintly visible above the jet is a red sprite, another type of upper-atmosphere lightning with branching, crimson arms. **• *Samit Saha/ Basudeb Chakrabarti/ Soumyadeep Mukherjee***

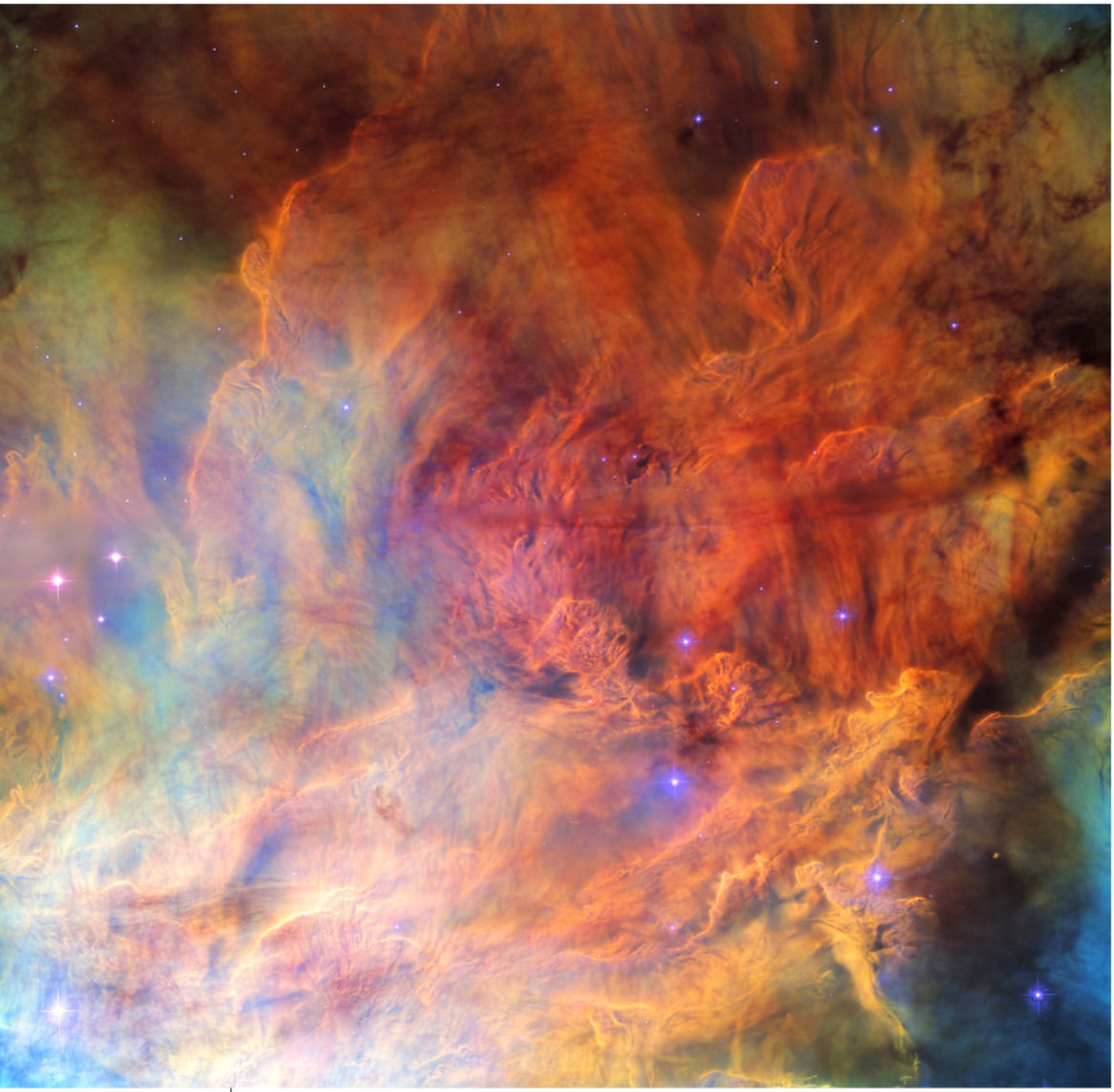
5. MONKEY BUSINESS

The Monkey Head Nebula (NGC 2174) is a star-forming region 6,400 light-years distant in Orion. The hot winds and radiation of the young stars have cleared out the nebula's interior. This image comprises 42.4 hours of observations with a 10-inch scope in the Hubble palette.
• *Oleg Bouevitch*

6. SOUTHERN SPLENDOR

Bright emission and reflection nebulae contrast with dark rifts and pillars of dust at the heart of the Carina Nebula (NGC 3372), the most impressive emission region in the sky. This image was taken with over three nights with a 20-inch scope.
• *Stephen Devine*

SEND YOUR IMAGES TO: readergallery@ astronomy.com.
Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures.



DEEP IN THE LAGOON'S HEART

Star clusters come in many shapes and sizes, but most have the decency to declare their stellar natures. The rules apparently don't apply to NGC 6530, however — at least in this portrait. The turbulent gas clouds of the Lagoon Nebula (M8) in Sagittarius conspire to envelop and largely obscure the cluster's few thousand stars. Ultraviolet radiation streaming from these young suns energizes the surrounding hydrogen, causing it to glow with a distinctive reddish hue. Astronomers created this image of NGC 6530's central region through observations made with the 2.4-meter Hubble Space Telescope and the 2.6-meter VLT Survey Telescope in Chile. ESA/HUBBLE & NASA/ESO/O. DE MARCO

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August 2023

Saturn takes center stage

» Early August offers us a final chance to enjoy the beautiful gathering of evening planets. The western sky features Mercury, Venus, and Mars in a nearly straight line that cuts across southern Leo the Lion.

Although **Venus** appears much brighter than the other two worlds, it also lies closest to the horizon. The planet shines at magnitude –4.3 from its position 19° east of the Sun. The gap between the two closes rapidly, however, and you'll have a hard time spotting Venus after August's first week. Despite its low altitude, it's worth targeting the planet through a telescope. On the 1st, you'll get an impressive view of a disk that spans 54" but appears only 6 percent lit.

Venus passes between the Sun and Earth at inferior conjunction August 13. It then returns to view in the eastern sky before dawn during the month's final week. A telescope once again delivers fine views of a large disk with a thin crescent phase. On the 31st, the planet shows a 51"-diameter disk that's 10 percent illuminated.

The middle object in our evening trio is **Mercury**. Although it's barely 1 percent as bright as Venus, the innermost world nevertheless shows up easily as it delivers its finest apparition of the year. Mercury reaches its peak around the time of greatest elongation August 10, when it lies 27° east of the Sun and stands 14° high in the west an hour after sundown. The planet then shines at magnitude 0.4, significantly brighter than any of Leo's stars.

Mercury remains visible for most of August, plenty of time to track its changing appearance through a telescope. On the 1st, the planet displays a disk that measures 7" across and appears 62 percent lit. But Mercury probably looks best around the 25th, when it spans 10" and the Sun illuminates 21 percent of its Earth-facing hemisphere.

The faintest of our evening planets stubbornly holds on in the western sky, remaining visible well after Venus and Mercury have disappeared from view. **Mars** glows at magnitude 1.8 this month and stands out more for its ruddy color that its brightness. Unlike its evening companions, the Red Planet hardly merits a glance through your scope. It shows a featureless disk measuring just 4" across.

Mercury, Venus, and Mars don't stick around long after sunset, but our next planet graces the sky nearly all night. **Saturn** reaches opposition August 27, when it lies opposite the Sun in our sky and remains visible from dusk to dawn. The ringed planet also comes closest to Earth at opposition, so it shines brightest and appears largest through a telescope. The outer planet glows at magnitude 0.4 among the much dimmer background stars of Aquarius the Water-bearer.

As nice as it is to view Saturn with the naked eye or binoculars, you haven't really experienced this world until you point a telescope in its direction. At opposition, the planet measures 19" across the equator while the spectacular rings span 43" and tilt 9° to our line of sight. Several of its satellites should be obvious as well. The brightest is 8th-magnitude Titan, which shows up through any scope. You can watch it change position from night to night just as Dutch astronomer Christiaan Huygens did when he discovered it in 1655. Tethys, Dione, and Rhea glow at 10th magnitude and show up nicely with a 10-centimeter instrument. Moderately high magnification helps them pop into view.

About five hours after Saturn rises, **Jupiter** pokes above the eastern horizon. The solar system's largest planet makes a fine sight once it climbs high in the north as dawn approaches. Jupiter shines at magnitude –2.5 against the backdrop of Aries the Ram. A telescope reveals its 42"-diameter disk and dynamic atmosphere along with four bright moons.

The starry sky

Only a few constellations actually look like the object, creature, or character for which they are named. Perhaps the best example of a star pattern matching its namesake is Crux the Cross. But a close contender passes nearly overhead not long after darkness falls these August evenings. Scorpius closely resembles a scorpion, although some people simply see it as a backward question mark. And the Aboriginal people in Arnhem Land in northern Australia see the pattern as a crocodile known as Baru.

The most famous part of the Scorpion is its stinger, the pair of stars — Shaula (Lambda [λ] Scorpii) and Lesath (Upsilon [υ] Sco) — that mark the end of the arachnid's tail.

Most celestial cartographers depict the stinger as coming to a sharp end at one of these two stars. Intriguingly, some renderings show these suns as the end of the tail but not the stinger itself. The stinger is a further protuberance normally not marked by an extra star.

Although German astronomer Johann Bayer designated Shaula as Lambda Sco in his 1603 masterpiece *Uranometria*, it shines at magnitude 1.6 and actually is Scorpius' second-brightest star, after Antares. Normally, a constellation's number two star would be Beta (β), but that honor goes to a magnitude 2.6 star in northern Scorpius. Well-known author James Kaler and others have suggested that this might be because Shaula lies so far south that Bayer viewed it through thick layers of air that dimmed it significantly. (Though this doesn't explain why some of the Scorpion's stars even farther south have Greek letters earlier in the alphabet.)

STAR DOME

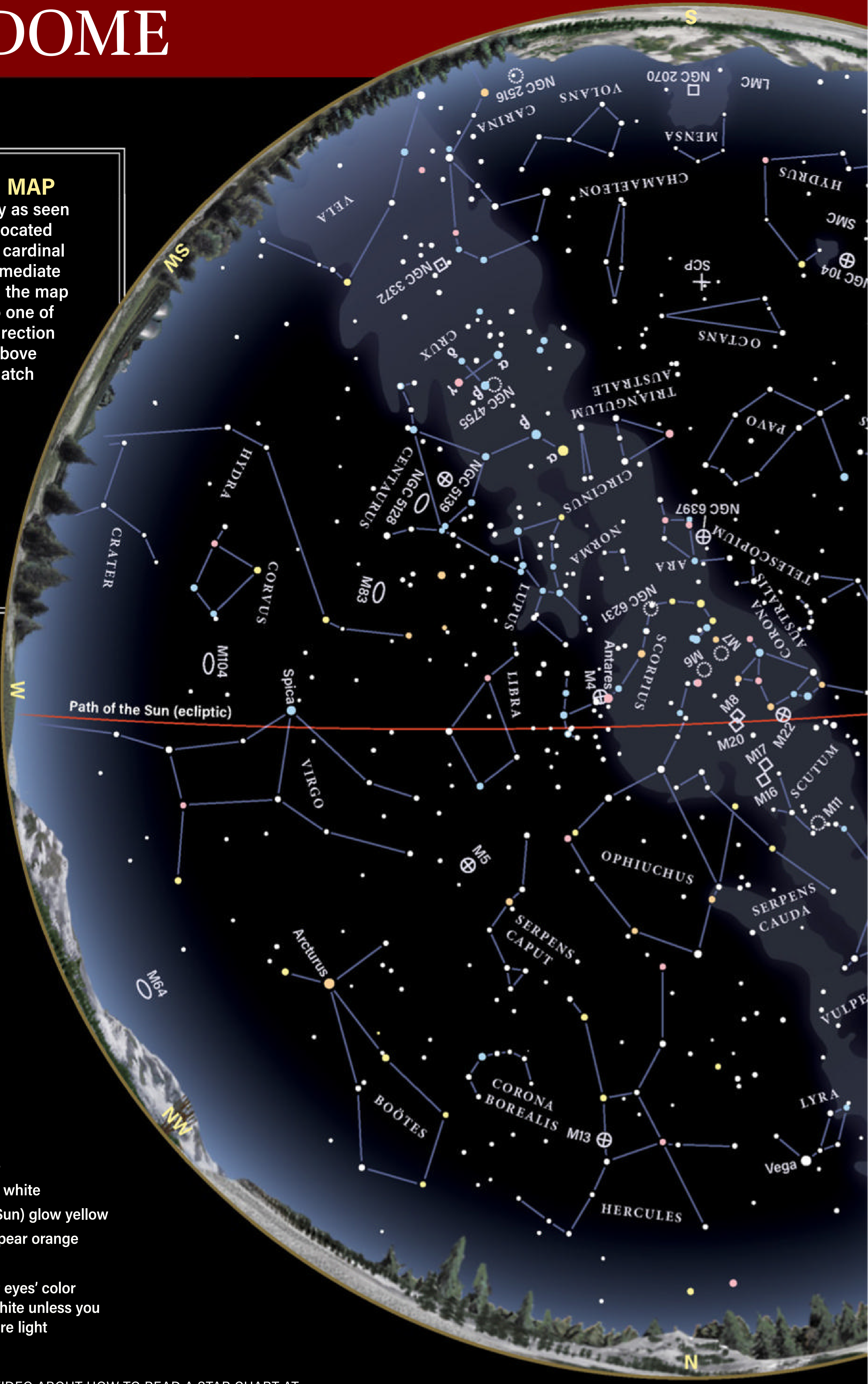
HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. August 1
8 P.M. August 15
7 P.M. August 31

Planets are shown at midmonth


S
SW
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NGC 2516
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NGC 2070
LMC
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CHAMAELEON
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VELA
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SCP
NGC 104
OCTANS
CRUX
α
β
γ
NGC 4755
TRIANGULUM AUSTRALE
PAVO
CENTAURUS
NGC 5128
NGC 5139
CIRCINUS
NGC 6397
HYDRA
CRATER
CORVUS
M83
NORMA
ARA
TELESCOPIUM
CORONA AUSTRALIS
LUPUS
NGC 6231
M7
M6
M104
Antares
M4
SCORPIUS
LIBRA
Spica
Path of the Sun (ecliptic)
VIRGO
M8
M20
M22
M17
M16
SCUTUM
M11
M5
OPHIUCHUS
SERPENS CAUDA
SERPENS CAPUT
Arcturus
M64
VULPE
BOÖTES
CORONA BOREALIS
M13
LYRA
Vega
HERCULES

MAP SYMBOLS

- ◌ Open cluster
- ⊕ Globular cluster
- □ Diffuse nebula
- ⌖ Planetary nebula
- ⬭ Galaxy

STAR MAGNITUDES

● Sirius

●	0.0	•	3.0
●	1.0	•	4.0
•	2.0	·	5.0

STAR COLORS

A star's color depends on its surface temperature.

- 🟦 The hottest stars shine blue
- ⬜ Slightly cooler stars appear white
- 🟨 Intermediate stars (like the Sun) glow yellow
- 🟧 Lower-temperature stars appear orange
- 🟥 The coolest stars glow red
- ⬜ Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

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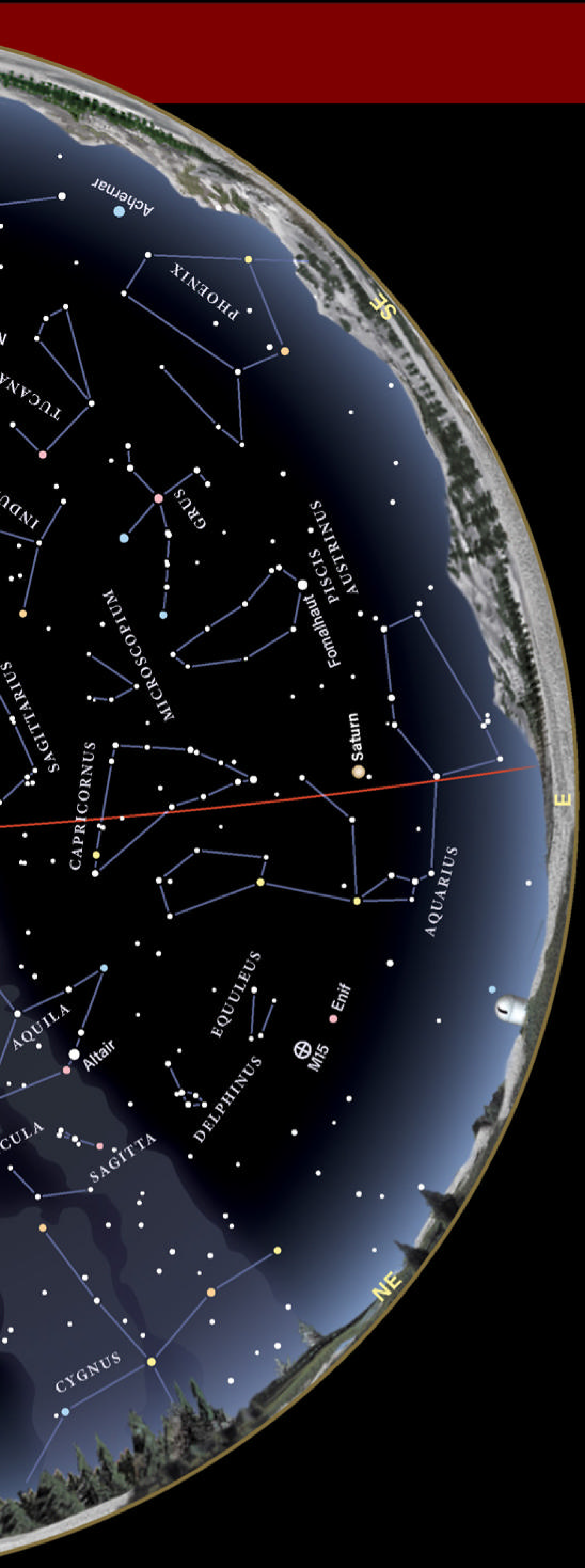
Achernar
PHOENIX
TUCANA
INDU
GRUS
PISCIS AUSTRINUS
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MICROSCOPIUM
SAGITTARIUS
CAPRICORNUS
Saturn
AQUARIUS
SE
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NE
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Enif
M15
DELPHINUS
AQUILA
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CULA
CYGNUS

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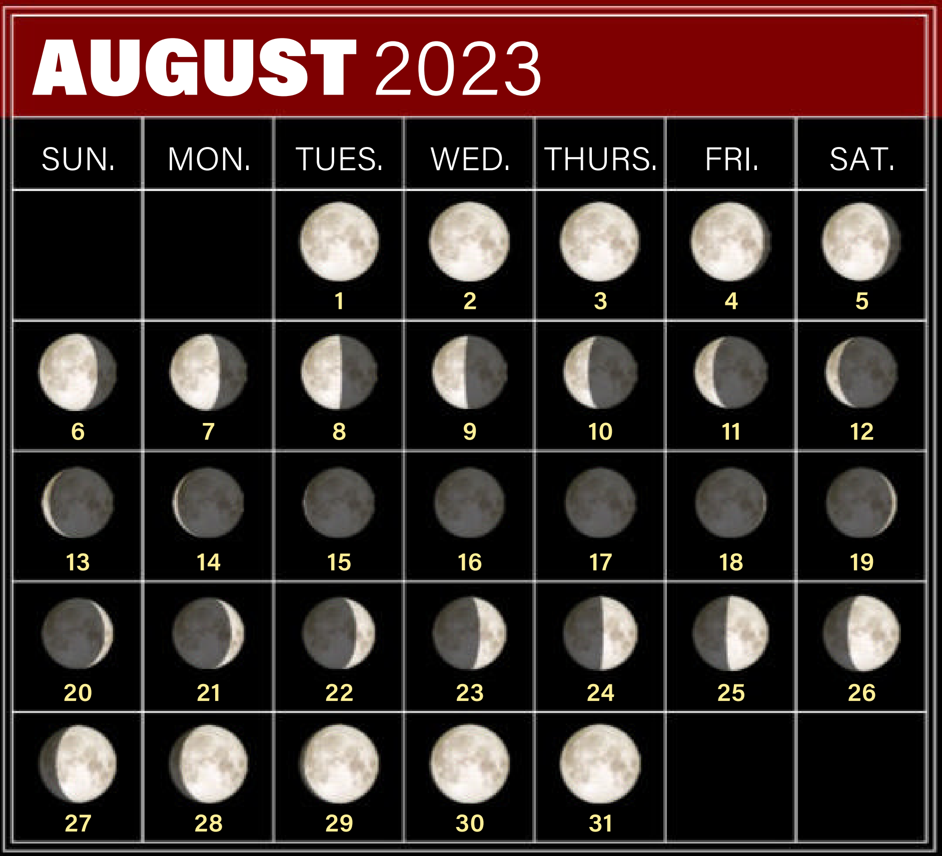

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1	Full Moon occurs at 18h32m UT
2	The Moon is at perigee (357,311 kilometers from Earth), 5h52m UT
3	The Moon passes 2° south of Saturn, 10h UT
4	The Moon passes 1.5° south of Neptune, 22h UT
8	The Moon passes 3° north of Jupiter, 10h UT
	Last Quarter Moon occurs at 10h28m UT
9	The Moon passes 3° north of Uranus, 1h UT
10	Mercury is at greatest eastern elongation (27°), 2h UT
13	Venus is in inferior conjunction, 11h UT
16	New Moon occurs at 9h38m UT
	The Moon is at apogee (406,634 kilometers from Earth), 11h54m UT
18	The Moon passes 1.1° north of asteroid Pallas, 11h UT
	The Moon passes 7° north of Mercury, 11h UT
	The Moon passes 2° north of Mars, 23h UT
23	Mercury is stationary, 5h UT
24	First Quarter Moon occurs at 9h57m UT
25	The Moon passes 1.1° north of Antares, 2h UT
27	Asteroid Flora is at opposition, 8h UT
	Saturn is at opposition, 8h UT
29	Uranus is stationary, 3h UT
30	The Moon is at perigee (357,181 kilometers from Earth), 15h54m UT
	The Moon passes 2° south of Saturn, 18h UT
31	Full Moon occurs at 1h36m UT

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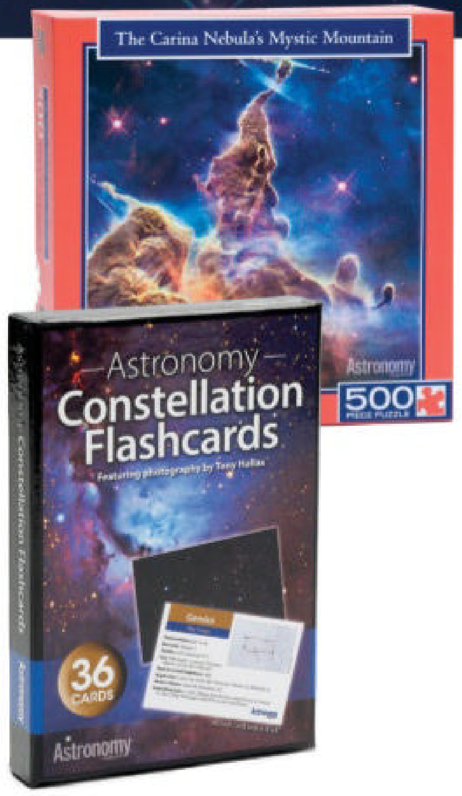
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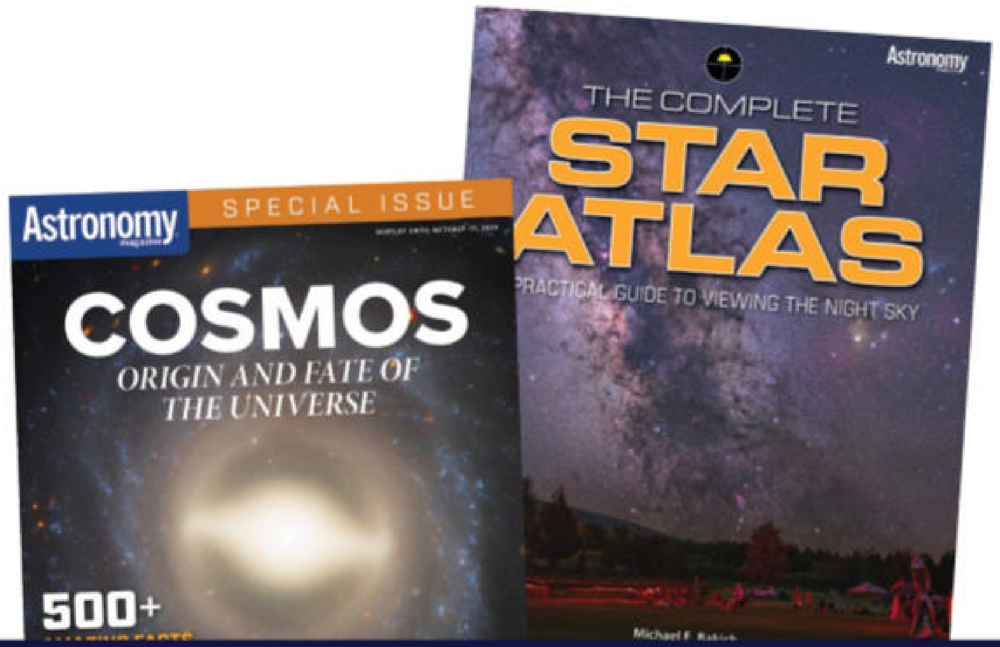
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